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Partial Cutting and Helicopter Yarding on Environmentally Sensitive Floodplains in Old-growth Hemlock/Spruce Forests

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Partial Cutting and Helicopter Yarding on Environmentally Sensitive Floodplains in Old-growth Hemlock/Spruce Forests

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SUMMARY

At Naden Harbour on the Queen Charlotte Islands, B.C., partial cutting and yarding with a Sikorsky S 64-E Sky-Crane helicopter has been used to remove old-growth Sitka spruce, western hemlock, and western redcedar from environmentally sensitive floodplain sites. Between 1986 and 1989, 67 500 m^3 of timber was logged from 141 ha in 14 partially cut blocks.

A retrospective study of the development of these partial cutting operations was conducted. Four case studies are presented to describe the type of floodplain sites on which partial cutting has been used. Various forestry concerns about partial cutting are reviewed, including the silvicultural implications, the damage to residual trees, blowdown following cutting, and the protection of important fish habitats. The procedures used to select appropriate sites, mark individual trees, and conduct falling, yarding, and post-logging clean-up are described.

The partial cutting and helicopter yarding at Naden Harbour has been successful in meeting the objectives of (1) harvesting a previously inaccessible volume of timber and (2) protecting environmentally sensitive fish habitats. The methods and procedures developed here for partial cutting and helicopter yarding may be appropriate on a variety of other sites in coastal British Columbia where objectives such as protecting wildlife habitats, retaining aesthetic values, or maintaining the stability of steep slopes require or favour partial cutting over conventional clearcutting and cable yarding.

Most of the silvicultural concerns for partial cutting in old-growth coastal forests have been overcome at Naden Harbour. Most blocks are expected to be windfirm and will become fully stocked uneven-aged stands that will support another harvest before the normal rotation period. Procedures for improving the condition of the residual stand are identified in this report. As well, recommendations are made to ensure that the silvicultural objectives for the residual partially cut stand are set before tree marking and cutting begin.

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Rob Volkman and Doug Corrin of Coast Forest Management Ltd., Victoria, assisted with cruise information, described the engineering and layout procedures, provided maps, and thoroughly reviewed draft reports. Dom Aquino of Coast Forest Management drafted the figures.

Del Williams of the Ministry of Forests, Queen Charlotte City, assisted with silvicultural terminology and provided access to Ministry of Forests reports. He also provided comments on a draft report. Mike Hennigan provided the insight of a falling contractor on layout and falling procedures and reviewed a draft.

The report was prepared under a contract with the Research Branch of the B.C. Ministry of Forests. Steve Chatwin and Ian Graeme of the Research Branch administered the contract and co-ordinated reviews of the draft reports. Funding was provided by Forestry Canada and the B.C. Ministry of Forests under the Forest Resource Development Agreement (FRDA) and is gratefully acknowledged.

TABLE OF CONTENTS

SUMMARY iii

ACKNOWLEDGEMENTS iv

1 INTRODUCTION 1

2 ENVIRONMENTALLY SENSITIVE SITES AT NADEN HARBOUR 2

3 PARTIAL CUTTING AND HELICOPTER YARDING 5

3.1 Procedures for Partial Cutting on Environmentally Sensitive Sites 6

4 CASE STUDIES 7

4.1 Case Study 1: Block 1 of Cutting Area HN-1, Lignite Creek 9
4.2 Case Study 2: Block HN-5, Tiens and Privation Creeks 14
4.3 Case Study 3: Block HN-7, Eden Lake 20
4.4 Case Study 4: Block H-8, Cave Creek 26

5 DISCUSSION 28

5.1 Blowdown of Residual Trees 29
5.2 Damage to Residual Trees 30
5.3 Utilization Levels and Slash Accumulations 30
5.4 Silvicultural Concerns 30

6 CONCLUSIONS 31

7 LITERATURE CITED 33

8 LIST OF PERSONAL COMMUNICATIONS 34

APPENDICES

1 Definitions of partial cutting 35

2 Procedures for partial cutting and helicopter yarding on environmentally sensitive floodplain sites 36

3 Stream classification in the Coastal Fisheries-Forestry Guidelines 41

4 Husby Forest Products Ltd. special treatments for helicopter logging 42

TABLES

1	Description of the four case studies	7
2	Summary of pre- and post-logging cruise plot information in cutblocks HN-1, HN-5, and HN-7	9
3	Percentage of stand volume by timber grade in cutblock HN-1, pre- and post-logging	11
4	Summary of net merchantable volume per tree in cutblock HN-1, pre- and post-logging	11
5	Percentage of stand volume by timber grade in cutblock HN-5 pre- and post-logging	17
6	Summary of net merchantable volume per tree in cutblock HN-5, pre- and post-logging	17
7	Percentage of stand volume by timber grade in cutblock HN-7, pre- and post-logging	23
8	Summary of net merchantable volume per tree in cutblock HN-7, pre- and post-logging	23

FIGURES

1	Map of the Queen Charlotte Islands	1
2	Map of Naden Harbour	3
3	Typical Class I floodplain stream at Naden Harbour	4
4	Evidence of water movement on floodplain forest site	4
5	S 64-E Sky-Crane helicopter	6
6	Summary of net merchantable volume (m^3/ha) in cutblocks HN-1, HN-5, and HN-7 before and after logging, based on resurvey of timber (cruise) plots	8
7	Summary of number of merchantable stems per hectare in cutblocks HN-1, HN-5, and HN-7 before and after logging	8
8	Map of case study 1, cutting area 1 of block HN-1, Lignite Creek	10
9	Block HN-1 after partial cutting and helicopter yarding	13
10	Block HN-1 after partial cutting and helicopter yarding	13
11	Small stream in block HN-1 after partial cutting and helicopter yarding	14
12	Small stream in block HN-1 after partial cutting and helicopter yarding	15
13	Map of case study 2, block HN-5, Tiens and Privation Creeks	16
14	Block HN-5 after partial cutting and helicopter yarding	18
15	Streamside area in block HN-5 after partial cutting and helicopter yarding	19
16	Double girdled hemlock in block HN-5 after silvicultural treatment	20
17	Planted trees and spaced advanced regeneration in block HN-5 after silvicultural treatment	21
18	Map of case study 3, block HN-7, Eden Lake tributaries	22

19 Block HN-7, viewed from nearby road, after partial cutting and helicopter yarding 24
20 Block HN-7 after partial cutting and helicopter yarding 24
21 Stream in block HN-7 after partial cutting and helicopter yarding 25
22 Map of case study 4, block H-8, Cave Creek 27
23 Block H-8 after partial cutting and helicopter yarding 28

1 INTRODUCTION

Partial cutting[1] in the coastal old-growth forests of British Columbia is of increasing interest to foresters, biologists, and the general public. It allows some timber to be harvested while fish habitats are protected, live trees and snags are retained for wildlife habitat, and aesthetic and recreational values are maintained (Hatfield 1988).

Several reasons are often cited to explain why partial cutting is not currently practiced in the coastal forests (Sanders and Wilford 1986; Standish 1989; Nelson *et al.* 1990). These include the lack of suitable harvesting equipment to remove the large individual logs in a safe and economical manner, the lack of crews trained in partial cutting, the risk of damage to residual trees, and the risk of blowdown in the remaining stand. In addition, clearcutting is believed to be the best method for promoting the rapid regeneration of desired tree species. By contrast, partial cutting in the coastal forests is believed to maintain poor quality residual trees, favour the regeneration of shade-tolerant species, and inhibit the regeneration of light-requiring species.

Heavy lift helicopters provide a yarding system that can eliminate many of the problems that make partial cutting impractical. In coastal British Columbia, however, virtually all helicopter logging that has occurred has involved clearcutting.

At Naden Harbour, on the northwest corner of the Queen Charlotte Islands (Figure 1), a method of partial cutting and yarding with heavy lift helicopters has been developed to remove trees from environmentally sensitive floodplain and streamside sites. These sites provide an excellent demonstration — and opportunity for evaluation — of partial cutting in environmentally sensitive areas.

FIGURE 1. Map of the Queen Charlotte Islands.

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[1] Partial cutting is defined as "tree removal other than clearcutting, i.e., taking only part of the stand" (Ford-Robertson 1971). It is used throughout this report to describe the silvicultural system used at Naden Harbour to remove individual trees or groups of trees from uneven-aged stands and to leave an uneven-aged stand for another harvest at a later date. This term is used in place of "selective cutting" or "selection cutting" which are not appropriate terms to describe the harvesting operations at Naden Harbour. A more thorough discussion of silvicultural terminology is in Appendix 1.

This report provides a review of the operational experience with a heavy lift helicopter and partial cutting at Naden Harbour. It includes a qualitative, post-logging assessment of the success of this method of logging in protecting environmentally sensitive sites while removing timber.

Four case studies which describe the stand conditions after logging are presented to illustrate the type of sites on which partial cutting and helicopter yarding have been used. The report describes how areas are selected for partial cutting and outlines the elaborate set of procedures that have been developed for engineering, falling, yarding, and post-logging clean-up in the partially cut areas.

2 ENVIRONMENTALLY SENSITIVE SITES AT NADEN HARBOUR

The Naden Harbour area is in the Wet Hypermaritime and Very Wet Hypermaritime subzones of the Coastal Western Hemlock biogeoclimatic zone (B.C. Ministry of Forests and Lands 1988). These subzones occur along the outer British Columbia coast on western and northern Vancouver Island and on the lower slopes of the Coast Range at elevations from sea level to 600 m. They include most of the Queen Charlotte Islands. The climate is characterized by mild, wet winters with little snowfall and cool moist summers. Mean annual rainfall in the Naden Harbour area is 1838 mm (Banner and Pojar 1987).

The old-growth forests are dominated by western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), and western redcedar (*Thuja plicata*), and have a history of disturbance by wind and mass movements rather than by fire. Typically, western hemlock is more abundant than Sitka spruce in old stands, but large dominant spruce protrude above the main canopy (Banner and Pojar 1987). Large areas of scrub timber and numerous bogs occur throughout the forest. The best timber stands are along the streams and on floodplains (Townshend 1981).

The two Forest Licences in the Naden Harbour area (Figure 2) include the watersheds of several large creeks and river systems (Davidson, Lignite, Haines, and Cave creeks, and Naden River, each 10 000–15 000 ha). Timber volumes on these sites typically range from 500 to 1200 m^3/ha. Some exceptional stands reach 1500 m^3/ha (R. Volkman, Coast Forest Management Ltd., pers. comm.).

These valuable stands of large trees are closely associated with very high fisheries values on the floodplain. The highly productive forest sites are typified by a high density of small, low gradient streams (less than 3 m wide and less than 2% gradient), meandering side channels, and soft stream banks. Many of the streams and backwater channels are less than 1 m wide and may be dry in the summer months. In the fall and winter months, occasional low velocity flooding of the floodplain occurs when streams rise above the low banks during heavy rains (Figures 3 and 4).

The importance of these low gradient streams and their associated floodplain and streamside zones for fish habitat in coastal watersheds has been well documented (Hartman and Brown 1987). In the Naden Harbour area, the large, low gradient streams (such as Davidson and Lignite Creeks and their tributaries) provide spawning gravel habitat for pink salmon and chum salmon (*Oncorhynchus gorbuscha* and *O. keta*) whose young migrate from these streams to saltwater almost as soon as they hatch. The smaller low gradient streams that are tributary to Eden Lake provide similar gravel spawning habitat for sockeye salmon (*O. nerka*).

The pools and slow flowing waters in the very small tributary streams on the floodplain provide rearing habitat for coho salmon (*O. kisutch*) whose fry spend at least one summer and winter rearing in freshwater. Coho use a wide variety of habitats on the floodplain. Some are the small seasonal streams and pools of standing water with organic muck substrates which, in the dry season, are only seeps or discontinuous pools (Brown 1985; Hartman and Brown 1987). Particularly in winter, coho juveniles depend on the small, low velocity channels as habitat in which to avoid the higher velocity flows in the main channels (Bustard and Narver 1975).

Steelhead and cutthroat trout (*Salmo gairdneri* and *S. clarki*) tend to spawn in the main stream channels and to rear in riffle habitats in the main channels. In winter, however, the floodplain provides important habitats for them as well, and several age classes of steelhead and cutthroat are found in the very small ephemeral and intermittent streams with the over-wintering coho (Hartman 1987; Hartman and Brown 1987).

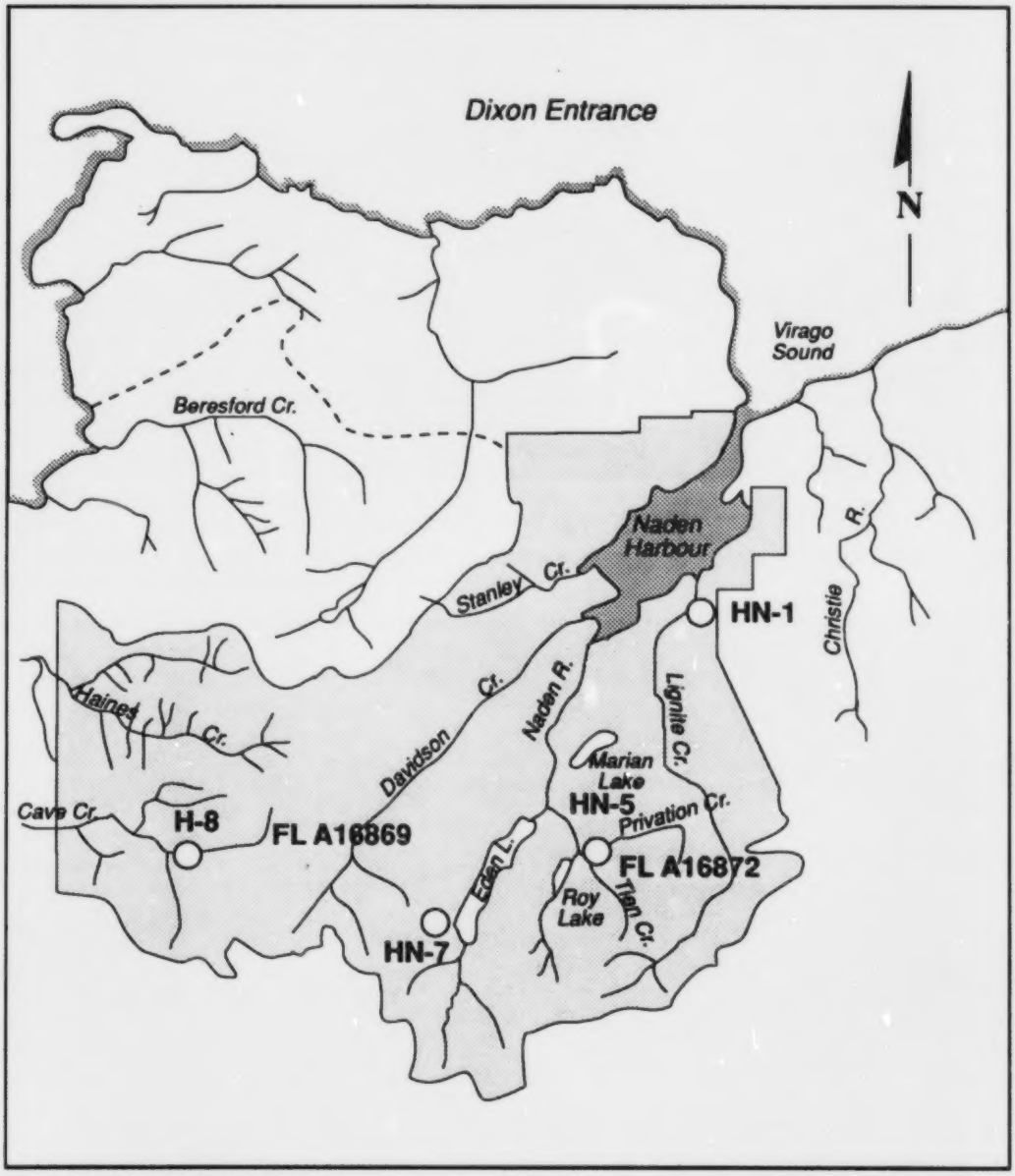

FIGURE 2. Map of Naden Harbour.

FIGURE 3. Typical Class I floodplain stream at Naden Harbour.

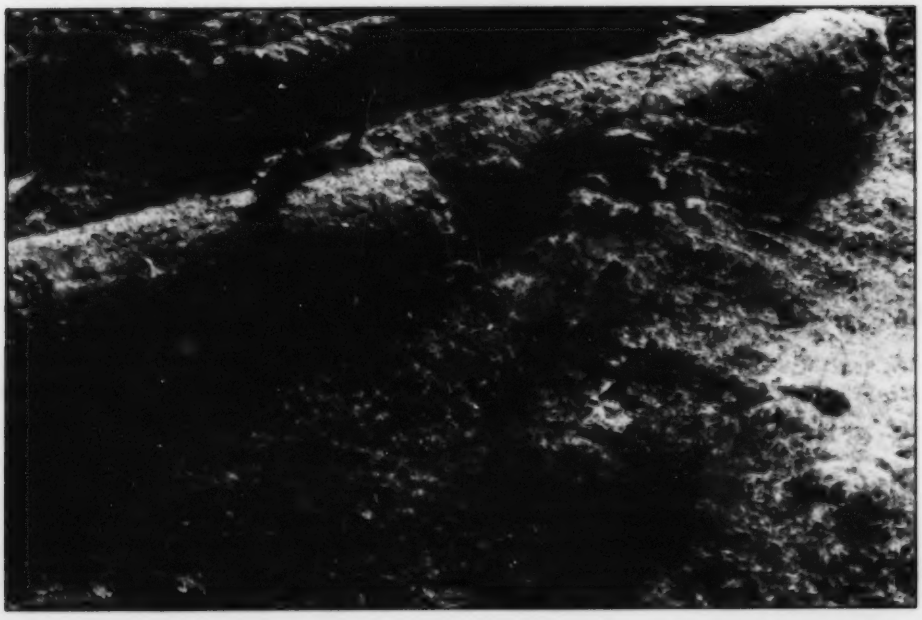

FIGURE 4. Evidence of water movement on floodplain forest site.

The conventional practices of clearcutting and cable yarding can cause considerable damage to the main channels and small side channels which provide these important fish habitats. Impacts include the removal of riparian vegetation, the physical alteration or disturbance of channels and banks, the destruction of large organic debris on the ground and in the stream, and the removal of future sources of large organic debris. During fall and winter flooding, the branches, tops and broken logs which are left on the floodplain after logging, accumulate in channels and cause blockages and erosion (Toews and Moore 1982).

To protect the integrity of these important habitats, trees are supposed to be felled and yarded away from streams, rather than across streams. Additional spur roads are recommended to facilitate better yarding (B.C. Ministry of Forests *et al.* 1988). In some cases, these practices are not physically possible or economically practical, however, because of the number of streams and small channels. Furthermore, the construction of extra roads and culverts damages fish habitats, and large amounts of slash remain on the floodplain after logging. For these reasons, conventional clearcutting and cable yarding on floodplain areas in Naden Harbour and other areas of the Queen Charlottes are often impractical for forest companies and are strongly discouraged by the regulatory agencies.

3 PARTIAL CUTTING AND HELICOPTER YARDING

Husby Forest Products Ltd. holds the two Forest Licences which provide the cutting rights to the timber in Naden Harbour (Figure 2).

In 1986, this company proposed partial cutting and helicopter yarding as a way to remove timber from the sensitive floodplains. They aimed to remove only those trees which could be felled and yarded without direct impact on the floodplain fish habitats. Partial cutting would retain standing trees and large natural debris on the ground to dissipate floodwaters. It would also minimize the amount of slash on the ground available for transport. The regulatory agencies supported this plan, which avoided the need for roads and culverts on the floodplain.

Over the 4-year period, 1986–1989, Husby Forest Products Ltd. removed 67 500 m^3 from 141 ha in 14 partially cut blocks. Four of these blocks are described as case studies in Section 4. Partial cutting amounted to 25% of the volume that was yarded by helicopter in the two Forest Licences and to about 5% of the total volume harvested during that period.

The helicopter used in the Naden Harbour operations was a Sikorsky S 64-E Sky-Crane (Figure 5). This helicopter has been used occasionally for clearcutting and partial cutting operations in the province since 1974. It was first certified for harvesting logs in Canada by the Ministry of Transport in May 1986 and became more readily available to forest companies after that. The machine used by Husby Forest Products Ltd. is leased from Erickson Air-Crane (Canada) Ltd. and is one of only seven available in the world for commercial use.

The S 64-E Sky-Crane is the most powerful single rotor helicopter used in commercial logging in the world and is the only one specifically designed for lifting heavy loads. Its lifting capacity of 9000 kg (20 000 lb) is twice the capacity of the next largest helicopter being used for logging. With its low airframe weight and heavy lift, the Sky-Crane provides the best available combination of heavy lift and economical operation. It is considered the only helicopter suitable for partial cutting in coastal old-growth forests (A. Pertile, Husby Forest Products Ltd., pers. comm.).

A smaller helicopter, the Sikorsky S 61-L, with a maximum lift of 4000 kg (9000 lb), is also used in helicopter yarding at Naden Harbour and other coastal British Columbia locations, but only in blocks that are clearcut. The greater lifting capacity of the S 64-E Sky-Crane makes it much better suited than the S 61-L for lifting large trees straight up through the canopies of partially cut areas.

FIGURE 5. S 64-E Sky-Crane helicopter.

Because the partially cut blocks at Naden Harbour were all on low elevation streamside and floodplain sites, the helicopter flight paths were level or slightly up hill. With an average flight distance of about 1 km, a turn of logs could be yarded every 2 minutes. Normal yarding production was approximately 150–200 m^3/hr, and at times as high as 300 m^3/hr. In comparison, a normal grapple yarder can average approximately 37 m^3/hr.

No roads were constructed within the helicopter blocks, but extensions to existing spur roads in adjacent blocks were sometimes built to provide shorter flight distances.

To date, all of the partial cutting at Naden Harbour has been on streamside or floodplain sites. The objective has been to remove some timber while protecting environmentally sensitive fish habitats. Plans are now being developed for two research trials with partial cutting and helicopter yarding on very steep unstable hillsides in the Rennell Sound area of the Queen Charlotte Islands. The aims of partial cutting on these areas will be (1) to maintain a live root web for slope stability and (2) to maintain a sufficiently intact canopy to avoid blowdown, while still removing some timber from sites too unstable for conventional logging (S. Chatwin, B.C. Ministry of Forests, pers. comm.).

3.1 Procedures for Partial Cutting on Environmentally Sensitive Sites

Partial cutting with helicopters requires more intensive planning and supervision at all phases of logging than do conventional clearcutting and cable yarding (R. Volkman and A. Pertile, Husby Forest Products Ltd., pers. comm.).

Husby Forest Products Ltd. and its forestry consultants, Coast Forest Management Ltd., have developed a comprehensive set of procedures for planning and block layout, tree marking, falling, yarding, and post-logging clean-up in blocks planned for partial cutting. The ministries of Forests and Environment and the Department of Fisheries and Oceans have co-operated in the development of these procedures, which are described in Appendix 2.

Marking and falling of individual trees is an essential feature of the partial cutting. These steps reflect the objectives set for the logging operation; they affect the condition of the remaining stand; and they determine the stand's species, height and age class structure. Improvement of the procedures for marking trees has been an important part of the evolution of partial cutting and helicopter yarding in the hemlock/spruce forests at Naden Harbour. These marking procedures are also described in Appendix 2.

4 CASE STUDIES

Four case studies are presented to illustrate the partial cutting of individually marked trees and the helicopter yarding of these trees at Naden Harbour. All four areas were logged between 1986 and 1989. Table 1 summarizes each case; Figure 2 shows their locations.

TABLE 1. Description of the four case studies. The estimates of timber volume, the percentages of the volume, and the number of stems removed by logging are based on a resurvey of timber cruise plots as described in Section 4.

Case study	Block	Location	Year	Size (ha)	No. stream channels	Volume m^3/ha	% Vol. removed	% Stems removed
1	HN-1	Lignite Cr.	1989	8.4	6	722.6	31.0	30.1
2	HN-5	Tiens/ Privation Cr.	1987	5.6	5	939.1	67.1	65.1
3	HN-7	Eden Lake	1987	7.5	7	1071.1	65.7	32.1
4	H-8	Cave Cr.	1987	7.3	5	-	-	-

The case studies were chosen to represent a variety of fish habitat and floodplain sites in different watersheds in Naden Harbour. Although the protection of fish habitat was a major objective in all the blocks described, the cutting objectives were different in each. These differences were reflected in the tree marking procedures.

The description of each case study is based on a review of the original cutting permit submission and on a field assessment of the block after logging. Notes were made on the partial cutting in each block, and on such factors as the condition of stream habitats, numbers of scarred and damaged residual trees, incidence of blowdown, and levels of slash. Written comments and field assessments made by Ministry of Forests and Ministry of Environment staff and a silvicultural review by Stewart & Ewing Associates Ltd. have been incorporated. However, the assessments are qualitative and retrospective because no assessment of any of these conditions had been made before logging. The environmental technician employed by Husby Forest Products Ltd. participated in the field work and helped to reconstruct the sequence of planning and harvesting in each block.

In three of the four blocks, case studies 1, 2 and 3, the centres of timber cruise plots established before logging and each individual tree in the plot were relocated after logging. The numbers of trees remaining in the plot and those that were damaged by logging or that subsequently blew down were noted. The number of stems, the volumes, the species distribution, and the grade distribution of the remaining stand were estimated as shown in Figures 6 and 7. In the fourth block, case study 4, pre-logging timber cruise information was not available.

The Ministry of Forests' standards for timber cruising require that at least one plot per hectare be established in cutting permit applications of less than 10 ha, and that at least four plots be established

within each distinct mapped forest cover type (B.C. Ministry of Forests 1990). In two of the three blocks for which the cruise was repeated, case studies 1 and 3, there are insufficient plots to meet these standards.

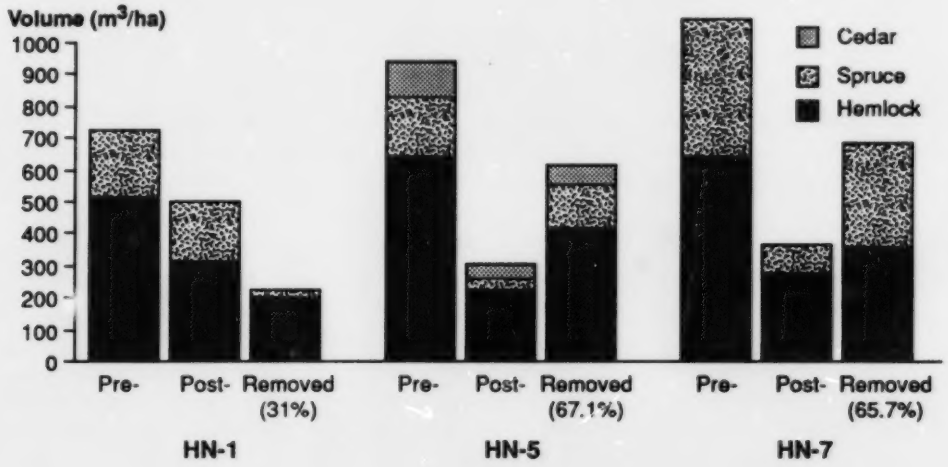

FIGURE 6. Summary of net merchantable volume (m^3/ha) in cutblocks HN-1, HN-5, and HN-7 before and after logging, based on resurvey of timber cruise plots.

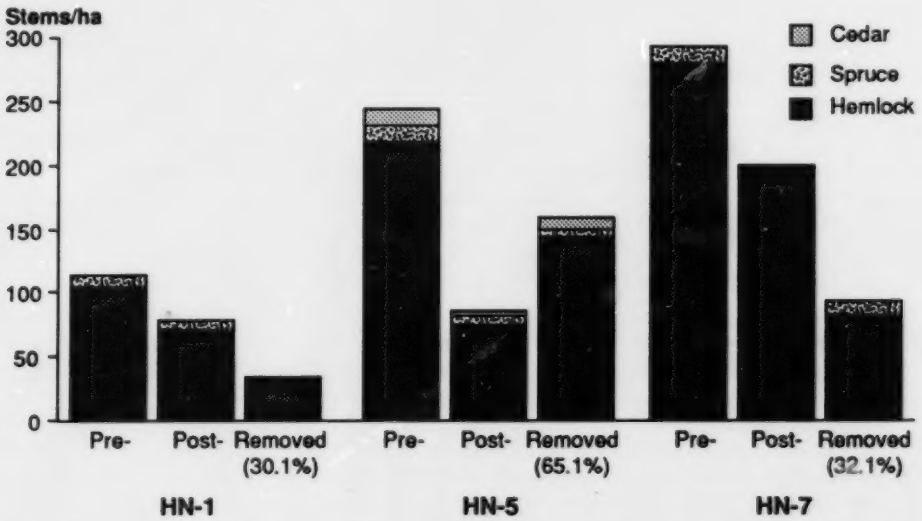

FIGURE 7. Summary of number of merchantable stems per hectare in cutblocks HN-1, HN-5 and HN-7 before and after logging. The number of stems per hectare includes all live trees and merchantable snags greater than 17.5 cm dbh. These are referred to as "good" and "dead potential" in the timber cruise. Non-merchantable trees and snags, referred to as "dead useless" in the cruise, are excluded. All trees less than 17.5 cm dbh are also excluded.

The Ministry of Forests' standard error requirement for timber cruising is 15% at 2 standard errors, but this is normally waived in small blocks when the sampling intensity requirements are met (B.C. Ministry of Forests 1990). The coefficients of variation and sampling error of the cruise information exceed ministry standards in case studies 2 and 3. The timber cruising information is summarized in Table 2.

TABLE 2. Summary of pre- and post-logging cruise plot information in cutblocks HN-1, HN-5, and HN-7

	HN-1		HN-5		HN-7	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
Area of block (ha)	8.4		5.6		7.3	
No. of timber types	2.0		1.0		1.0	
No. of cruise plots	5.0	5.0	5.0	5.0	4.0	4.0
No. of trees tallied	37.0	25.0	51.0	20.0	42.0	21.0
No. of merch. trees	26.0	17.0	37.0	13.0	30.0	11.0
Coefficient of variation	1.7	2.7	50.7	108.3	14.2	66.8
2 Standard errors	2.6	4.2	63.0	134.4	22.6	106.3

In the original cutting permit applications to cut these three blocks, the required sampling intensity and sampling error standards were met by including the blocks with a number of others proposed for partial cutting, to form one cutting permit application. Thus, the cruising standards were not met on any of the individual blocks but were met for the cutting permit as a whole. The volumes, species compositions, and grades reported for the individual blocks should therefore be read with caution. They provide interesting descriptions of the blocks before and after partial cutting, but are not suitable for statistical analysis.

Waste assessments have been completed for all the case studies, but are considered to be confidential by the Ministry of Forests (J. Guido, pers. comm.). At the time of logging the amount of avoidable waste allowed by the Ministry was 35 m^3/ha. We have used that standard for comparisons.

No routine assessments of the degree to which partial cutting has successfully protected fish habitats or met silvicultural standards have been carried out by government officials. There are no standard procedures to do this. The observations reported here are the opinions of the author. As much as possible, written assessments or comments made by others, have been included and referenced.

4.1 Case Study 1: Block 1 of Cutting Area HN-1, Lignite Creek

Description of the Cutting Area

Block 1 of HN-1 cutting area is in the lower Lignite Creek watershed on the east side of Naden Harbour (Figure 8). It was 8.4 ha in size, and was partially cut and yarded by helicopter in 1989.

Block 1 included timber on both sides of a 5–7 m wide, low gradient, tributary stream of Lignite Creek. This stream has several smaller tributaries and splits into two channels, creating a large island in the centre of the block. All of the streams are Class I as defined in the B.C. Coastal Fisheries-Forestry Guidelines (B.C. Ministry of Forests and Lands *et al.* 1988) (Appendix 3) and provide spawning and rearing habitat for several species of salmon. The number of stream channels and small side tributaries in this area made conventional road construction and cable yarding impractical. Protection of the fish habitat values would not have been possible. The block was therefore approved for partial cutting and helicopter yarding.

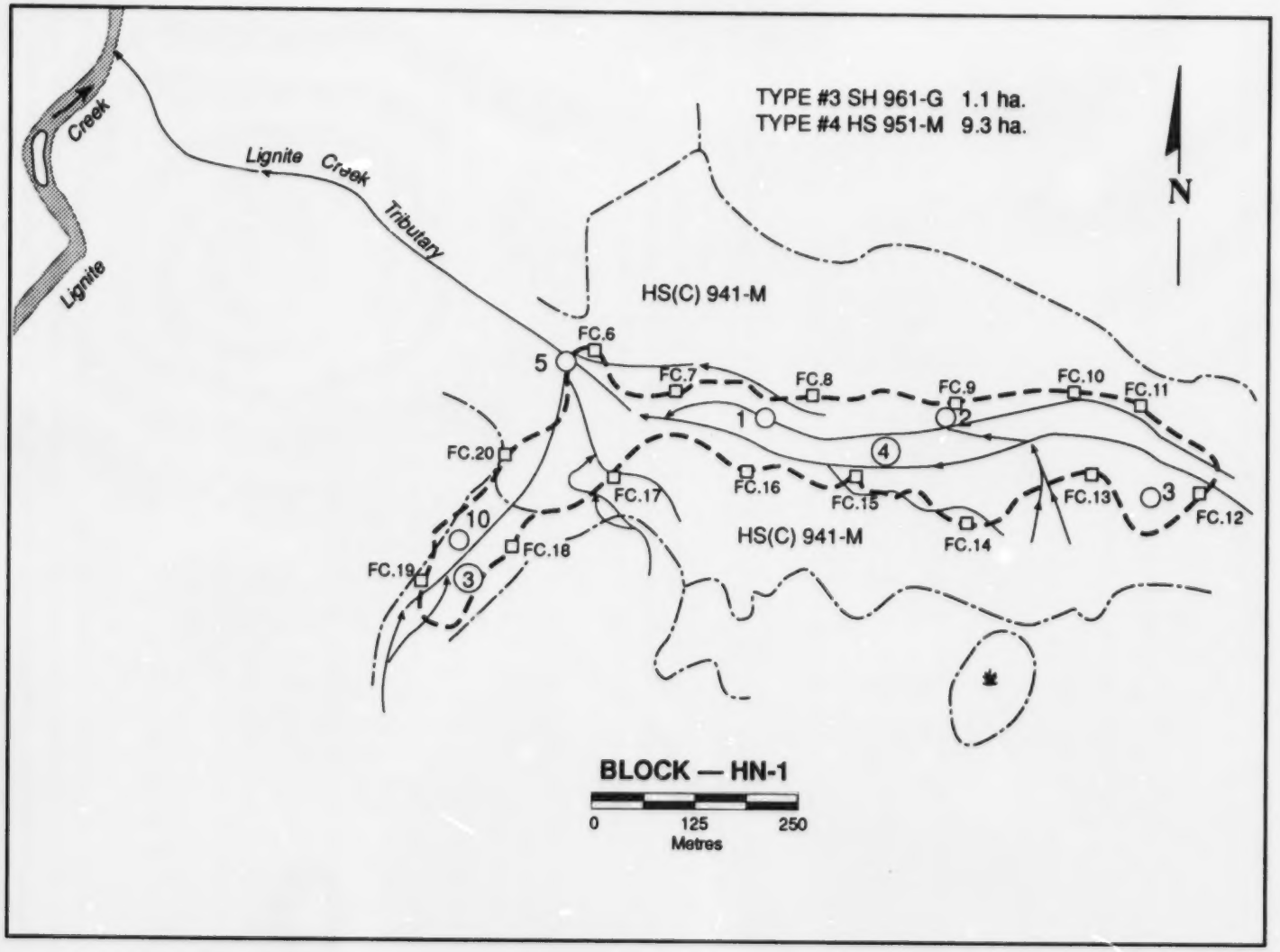

FIGURE 8. Map of case study 1, cutting area 1 of block HN-1, Lignite Creek. The locations of five cruise plots are shown.

Trees in this block were marked for partial cutting in 1988, with a method that reflects the experience gained in partial cutting in earlier blocks. The objectives in this block were to distribute the cut over the range of species and grades in the stand and to harvest approximately 30% of the total merchantable volume.

Timber Volumes, Species, and Grades Removed by Logging

Neither the timber cruise before logging nor the cruise after logging would be acceptable to the Ministry of Forests because there are insufficient plots (B.C. Ministry of Forests 1990). However, both the coefficient of variation and the sampiing error are well within acceptable ministry limits (see Table 2).

Figure 6 summarizes the cruise estimates of the timber volume, in total and by species before and after logging. Estimates of the number of stems per hectare before and after logging is in Figure 7. The distribution of the net merchantable volume by timber grade is shown in Table 3 and the net merchantable volume per tree by species is in Table 4.

TABLE 3. Percentage of stand volume by timber grade in cutblock HN-1, pre- and post-logging. "Peeler/lumber" includes grades A–F, "sawlog" includes grades H–J, and "pulp" includes grades K–Y.

	Total		Spruce		Hemlock		Cedar	
	Pre- %	Post- %	Pre- %	Post- %	Pre- %	Post- %	Pre- %	Post- %
Peeler/lumber	2.2	1.7	7.1	4.4	0	0	0	0
Sawlog	85.9	91.1	89.5	92.0	84.4	90.6	0	0
Pulp	12.1	7.2	3.4	3.5	15.7	9.3	0	0

TABLE 4. Summary of net merchantable volume per tree in cutblock HN-1, pre- and post-logging

	Total		Spruce		Hemlock		Cedar	
	Pre- (m^3)	Post- (m^3)	Pre- (m^3)	Post- (m^3)	Pre- (m^3)	Post- (m^3)	Pre- (m^3)	Post- (m^3)
Net merch. vol./tree	6.4	6.3	25.5	25.3	4.9	4.3	0	0

Before logging, the timber type in the partially cut portion of HN-1, which included all of block 1, was HS 951-M (9.3 ha) and SH 961-G (1.1 ha). The pre-logging cruise indicates that the net merchantable volume was 722.6 m^3/ha. Hemlock accounted for 93% of the 113 merchantable stems per hectare in the block and 71% of the net merchantable volume. Spruce accounted for 7% of the stems and 29% of the volume.

Peeler and lumber grades (A through F grades) were 2% of the net merchantable volume; sawlog grades (H, I, and J grade) accounted for 86%. Of the Sitka spruce volume, 7% was peeler and lumber grades and 90% was sawlog.

The resurvey and compilation of cruise plots indicate that a net merchantable volume of 498.4 m^3/ha remains after logging. The number of merchantable stems per hectare is 79. Thus, 30% of the merchantable stems and 31% of the original net merchantable volume were removed during logging.

Logging appears to have removed a slightly higher proportion of hemlock than was in the original stand. Before logging, 71% of the net merchantable volume was hemlock and 29% was spruce. After logging, hemlock accounts for 62% of the remaining volume, and the spruce component has increased to 38%. The harvest volume appears to have been 90% hemlock and 10% spruce.

The grade distribution of the timber in the stand was only slightly altered by logging. In the original stand, peeler and lumber grades constituted 2% of the volume. After logging, this high grade wood remained at 2% of the volume. The sawlog component of the stand increased from 86% of the stand before logging to 91% of the stand remaining after logging.

Net merchantable volume per tree was virtually unchanged, totalling 6.3 m^3 after logging. Net merchantable volume per spruce tree was also little changed, at 25.3 m^3 in the remaining stand.

Post-Logging Assessment

A visual assessment of this block and the analysis of cruise plots after logging indicate that the objectives of removing approximately 30% of the volume and 30% of the stems, and distributing the cut over the range of species and grades, have been met. The cutting ranges from a very light partial cut to several 0.5-ha patch cuts. An uneven-age stand with a mixture of species, diameters, and timber grades remains. There is a higher spruce component and a similar distribution of timber grades. Numerous good quality trees have been left behind in the areas between the patch cuts and near streams. Numerous snags remain standing. In some parts of the block, no trees have been removed at all. The block has not been "highgraded." Figures 9 and 10 illustrate block 1 of cutting area HN-1 after logging.

Because of the mixture of light partial cuts and small patch cuts, there is very little scarring of residual trees. In the five cruise plots resurveyed, 25 of the 37 trees tallied before logging remain standing after logging. Only one of the remaining trees, a small hemlock, has been damaged by logging. To date, none of the cruise plot trees have blown down and there are a few isolated blowdowns elsewhere in the block.

Where trees have been felled, slash is deep because branches are not broken. Slash does not compress in helicopter yarding as it does in conventional yarding. In the small patches where groups of trees have been logged, the slash appears to be deeper than in conventional clearcut areas because all trees are felled into the middle of the opening. The slash levels make walking difficult and may inhibit natural regeneration and planting. Site preparation by hand, and close supervision, will be necessary at the time of planting (D. Corrin, Malaspina College, pers. comm.).

Utilization levels were good and the waste assessment in this block was well within the 35 m^3/ha that was allowed by the Ministry at the time of logging (R. Volkman, Coast Forest Management Ltd., pers. comm.).

The Pre-Harvest Silviculture Prescription called for planting 400 stems of Sitka spruce after logging to minimize the impact of dwarf mistletoe (*Arceuthobium* spp.) on the hemlock. To date, no post-harvesting silvicultural surveys or treatments have been conducted. Many healthy trees in all height and age classes remain in this stand, but mistletoe is common in the standing hemlock. Because of the low number of trees removed, light may limit the success of Sitka spruce regeneration, but in the larger openings planted spruce is expected to grow (D. Corrin, Malaspina College, and M. Scott, B.C. Ministry of Forests, pers. comm.).

FIGURE 9. Block HN-1 after partial cutting and helicopter yarding.

FIGURE 10. Block HN-1 after partial cutting and helicopter yarding.

Stream habitat protection in this block has been excellent. Timber jacks were used to fall the marked trees away from streams and areas prone to flooding. Many large and small trees in the riparian areas adjacent to streams were not marked and remain standing. The stream banks and in-stream debris appear to be undisturbed by logging. Figures 11 and 12 illustrate the condition of the small streams in the block after logging.

FIGURE 11. Small stream in block HN-1 after partial cutting and helicopter yarding.

Because most trees along the stream edges remain standing and those that were felled along the stream edge were jacked away from the stream, there is relatively little logging slash close to the streams or in areas where it might move into stream channels during flood events. A stream clean-up crew of three people took two days to remove fine debris from small tributary streams.

An island of timber between two stream channels in the centre of the block was left completely uncut because of the signs of flooding and the difficulty of falling trees away from streams. Leaving this area was possible because the surrounding areas were partially cut. Had the surrounding areas been clearcut, it is likely that the island would have sustained considerable blowdown.

This block represents the current state of partial cutting in Naden Harbour. It is an excellent demonstration of the feasibility of removing 30% of the stand volume and leaving an uneven-aged stand with all species, sizes, and grades of trees represented, while protecting important fish habitats from the impacts of logging.

4.2 Case Study 2: Block HN-5, Tiens and Privation Creeks

Description of the Cutting Area

The HN-5 partial cutting area consisted of two isolated patches of timber bisected by Tiens and Privation creeks, tributaries of Roy Creek in the Naden River watershed. The two patches included a total area of 5.6 ha and were partially cut and yarded by helicopter in the summer of 1987. Figure 13 shows the block.

FIGURE 12. Small stream in block HN-1 after partial cutting and helicopter yarding.

Tiens and Privation creeks are low gradient streams approximately 7–10 m wide. The two parts of the block are approximately 1 km above a major barrier to anadromous fish passage, but both streams and their small tributaries support resident fish populations and are therefore Class 3 (Appendix 3). The Coastal Fisheries-Forestry Guidelines (B.C. Ministry of Forests and Lands *et al.* 1988) and normal streamside management practices on the Queen Charlottes precluded clearcutting both sides of these streams concurrently.

Both patches were largely surrounded by non-merchantable timber. One adjacent area was logged in 1981. Because of the shape of the patches of merchantable timber and the presence of the streams, road access and conventional harvesting were not practical for this area. Instead, partial cutting and helicopter yarding presented a reasonable alternative method of removing some volume of timber from both sides of the streams and still maintaining the fish habitat values.

The objectives in this block were to remove a high proportion of the merchantable timber volume, while avoiding a network of roads and stream crossings and protecting the integrity of both banks of the streams by partial cutting.

Timber Volumes, Species, and Grades Removed by Logging

With one plot established per hectare, the pre- and post-logging timber cruises of this block meet Ministry of Forests standards. However, the coefficients of variation and the sampling errors far exceed ministry standards (see Table 2).

Figure 6 summarizes the cruise estimates of the timber volume, in total and by species before and after logging. Estimates of the number of merchantable stems per hectare before and after logging are in Figure 7. The distribution of the net merchantable volume by timber grade is shown in Table 5 and the net merchantable volume per tree by species is in Table 6.

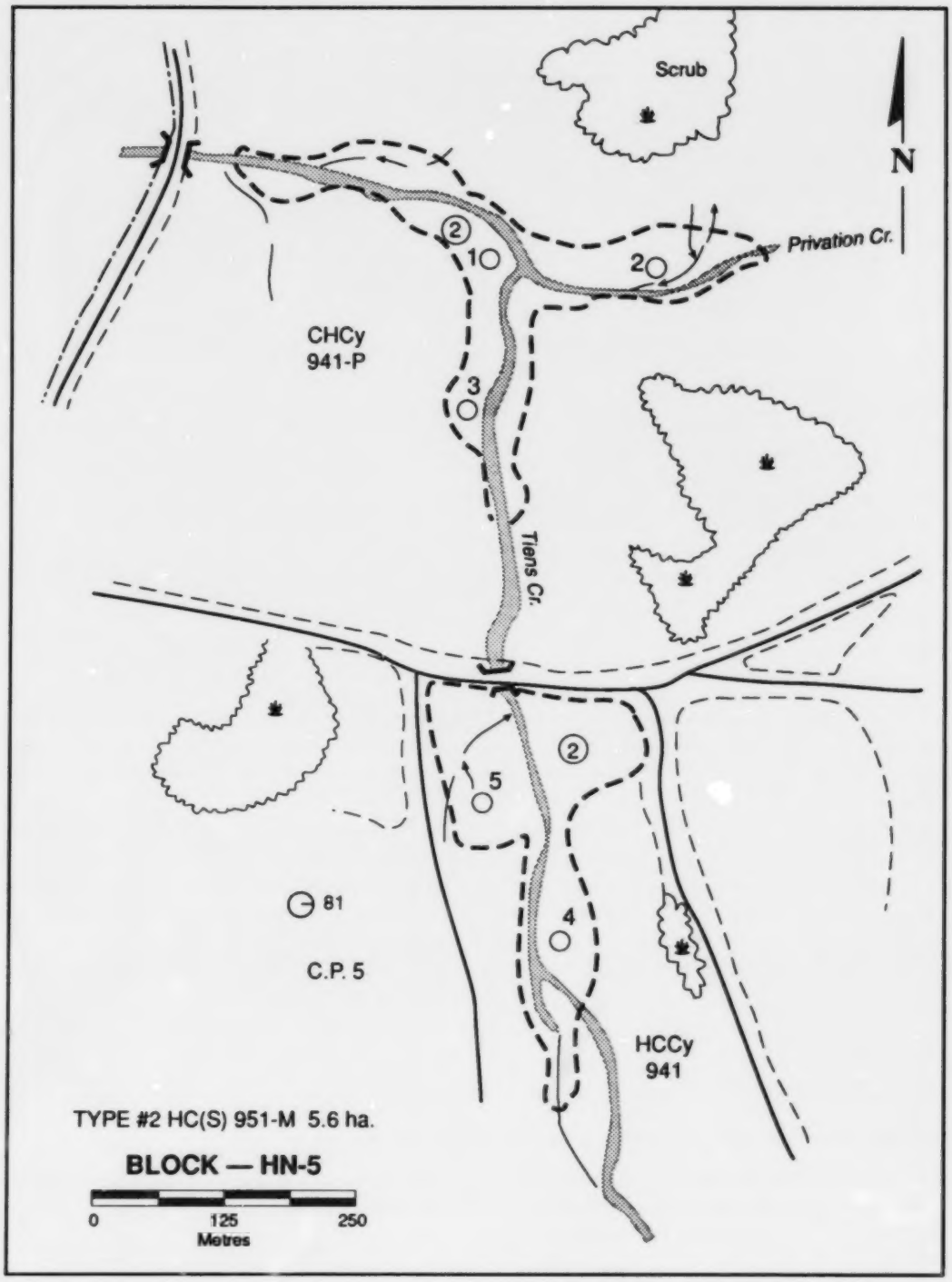

FIGURE 13. Map of case study 2, block HN-5, Tiens and Privation Creeks. The location of five cruise plots are shown.

TABLE 5. Percentage of stand volume by timber grade in cutblock HN-5, pre- and post-logging. "Peeler/lumber" includes grades A–F, "sawlog" includes grades H–J, and "pulp" includes grades K–Y.

	Total		Spruce		Hemlock		Cedar	
	Pre- %	Post- %	Pre- %	Post- %	Pre- %	Post- %	Pre- %	Post- %
Peeler/lumber	4.9	0	17.2	0	2.4	0	0	0
Sawlog	91.9	96.6	79.6	96.0	94.4	96.3	7.9	99.2
Pulp	3.1	3.3	3.1	4.0	3.2	3.8	2.1	0.9

TABLE 6. Summary of net merchantable volume per tree in cutblock HN-5, pre- and post-logging

	Total		Spruce		Hemlock		Cedar	
	Pre- (m^3)	Post- (m^3)	Pre- (m^3)	Post- (m^3)	Pre- (m^3)	Post- (m^3)	Pre- (m^3)	Post- (m^3)
Net merch. vol./tree	3.9	3.6	14.4	4.9	3.0	3.0	9.1	13.1

The timber type in both parts of the block was HC(S) 951. According to the cruise, the net merchantable volume before logging was 939.1 m^3/ha. Hemlock accounted for 90% of the 244 merchantable stems per hectare in the stand and 69% of the net merchantable volume. Sitka spruce accounted for 5% of the stems and 19% of the volume; redcedar was 5% of the stems and 12% of the volume.

Peeler and lumber grades accounted for 5% of the net merchantable volume; sawlogs were 92%. The original spruce volume was 17% peeler and lumber, and 80% sawlog grade.

The resurvey of cruise plots after logging indicates that the net merchantable volume remaining in the partially cut block is 309.1 m^3/ha. The number of merchantable stems per hectare is 85. This suggests that 65% of the merchantable stems and 67% of the original net merchantable volume have been removed.

The harvest appears to have closely approximated the original species composition of the stand. Hemlock composed 69% of the original volume and 66% of the harvest. Spruce composed 19% of the original volume of the stand and 24% of the harvest.

The elevated harvest of spruce has had the net effect of increasing the hemlock component of the stand from 69% of the original stand to 73% of the remaining stand. The spruce component of the stand has been reduced from 19% to 10%. The cedar component has been increased from 12% to 16%.

The greatest change is in the quality of the wood left in the stand. In the original stand, peeler and lumber grades accounted for 5% of the volume, and sawlog grades for 92%. After logging, the peeler and lumber grades have been removed and the sawlog component increased to 97% of the stand. The pulp grade component did not change at 3% of the total volume.

The greatest change is in the Sitka spruce component. Before logging, peeler and lumber grades accounted for 17% of the spruce volume. In the stand which remains after logging, none of that peeler and lumber grade volume remains. The spruce component is 96% sawlog and 4% pulp.

A separate cruise of one of the two patches undertaken after logging (14 plots) showed slightly different results. It indicated that 350 m^3/ha remain standing in the block, 70% hemlock and 30% spruce by volume.[2]

Post-Logging Assessment

The logging of this block has been described as a "streamside select" cutting.[3] Another Ministry of Forests report describes the logging as resembling a group or single tree selection.[4] The remaining block is described as an all-aged stand in which there is a possibility of a further harvest before the usual rotation elapses.

Visual observations in the two parts of the block after logging indicate that there has been light partial cutting near the streams, and small patch cuts farther from the streams. Tall trees remain standing in both the streamside areas and in the patch cut openings. Like block 1 of HN-1, there are small patches where virtually all trees have been removed. In this block, these small patches account for a significant portion of the total area of the block. Figures 14 and 15 illustrate the block after logging.

FIGURE 14. Block HN-5 after partial cutting and helicopter yarding.

Twenty trees remained in four cruise plots in the two parts of this block after logging. Three of these trees have blown down since 1987. A minor amount of blowdown has occurred in other parts of the block following logging. No logging damage was noted on the remaining trees in the cruise plots.

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2 Stewart and Ewing Associates Ltd. 1989. Streamside stand tending demonstration project. Unpubl. rep. to B.C. Min. For., Res. Br., Victoria, B.C.

3 Jablanczy, S. 1988. Helicopter logging report — F.L. A-16869 and A-16872. B.C. Min. For., Queen Charlotte City, B.C. Unpubl. rep. 2 p.

4 B.C. Ministry of Forests. [1988]. Silvicultural considerations: helicopter logging. Queen Charlotte City, B.C. Unpubl. rep. 2 p.

FIGURE 15. Streamside area in block HN-5 after partial cutting and helicopter yarding.

Block HN-5 is different than block 1 of HN-1 in that the streams in it were larger and bisected the block. There were fewer side channels, braided channels, and tributaries. Partial cutting was used to allow cutting on both sides of the streams. Thus, small patch cuts were created away from the stream edge and a higher percentage of the total volume in the stand has been harvested.

In the partially cut areas along the streams, only a few large trees have been removed and the stream banks and in-stream debris are essentially undisturbed. Large and small trees remain standing along the streams, but those removed tended to be large, high quality spruce. Most of the spruce volume and all of the spruce peeler and lumber grades have been removed. Although very different than block 1 of HN-1, the pre-logging objectives of removing a volume of timber while protecting streamside environments for fish habitat have been met.

Silvicultural Treatments

In 1989, a project to demonstrate stand tending practices in partially cut blocks was funded by the Ministry of Forests, Research Branch, and undertaken by Stewart & Ewing Ltd. on part of HN-5.[5] All of the residual stems in the block were assessed for their potential to contribute to future harvests or to contribute large organic debris to the streams. They were assessed for disease, logging damage, and growth form.

All trees damaged by logging, badly infected with dwarf mistletoe, or of generally poor form were double girdled. Girdling, rather than falling, was used to avoid adding to the slash load on the site, and to create snags for wildlife habitat. All red alder (*Alnus rubra*) and other minor species such as western yew (*Taxus brevifolia*) were left undisturbed.

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5 Stewart and Ewing, 1989.

Advanced regeneration greater than 2 m in height was thinned to a 2-m spacing and small open areas were fill planted with Sitka spruce 2+0 bareroot stock and western redcedar 2+0 plug stock at approximately 3-m spacing. A total of 500 seedlings were planted and protected against deer browsing with vexar screening. Observations in 1990 indicate that the planted spruce have suffered high mortality and show poor vigour. This is likely due to a stock problem (D. Corrin, Malaspina College, pers. comm.). The redcedar has a high survival and is growing well.

This silvicultural program was developed to ensure that the entire stand was fully stocked with a combination of acceptable mature timber, good quality advanced regeneration, and well-spaced planted seedlings with a mix of species. It demonstrates the type of silvicultural treatments that may be necessary in partially cut stands. Figures 16 and 17 illustrate these silvicultural treatments.

FIGURE 16. Double girdled hemlock in block HN-5 after silvicultural treatment.

4.3 Case Study 3: Block HN-7, Eden Lake

Description of the Cutting Area

This is a 7.5-ha block adjacent to Eden Lake. It was not accessible from the existing road systems when the adjacent areas were logged in 1976, and was left as a fire break or "leave" area between cutblocks. In the years following the adjacent logging, blowdown and dieback was significant and there were numerous snags. The block was partially cut and helicopter yarded in 1987.

FIGURE 17. Planted trees and spaced advanced regeneration in block HN-5 after silvicultural treatment.

Two Class I streams (Appendix 3) and some side channels cross the block. As well, there are several smaller tributaries and an area of braided stream channels. These are used by sockeye, coho, and probably steelhead for spawning and rearing. The block boundaries and the location of the streams are shown in Figure 18.

The block had a well-developed understory of hemlock and spruce on a well-drained site. The understory trees were protected from winds by the adjacent scrub forest. Partial cutting was aimed at removing blown down trees and large over-mature trees, and at leaving a canopy of younger trees and advanced understory trees. It was carried out by helicopter, to protect the stream channels and harvest trees that were not accessible by conventional yarding and road systems.

Timber Volumes, Species, and Grades Removed by Logging

The timber cruises before and after logging in this block do not meet Ministry of Forests standards, as only four plots were established. Both the coefficient of variation and the sampling error after logging exceed ministry standards (see Table 2).

Figure 6 summarizes the cruise estimates of the timber volume, in total and by species before and after logging. Estimates of the number of merchantable stems per hectare before and after logging are in Figure 7. The distribution of the net merchantable volume by timber grade is shown in Table 7 and the net merchantable volume per tree by species is in Table 8.

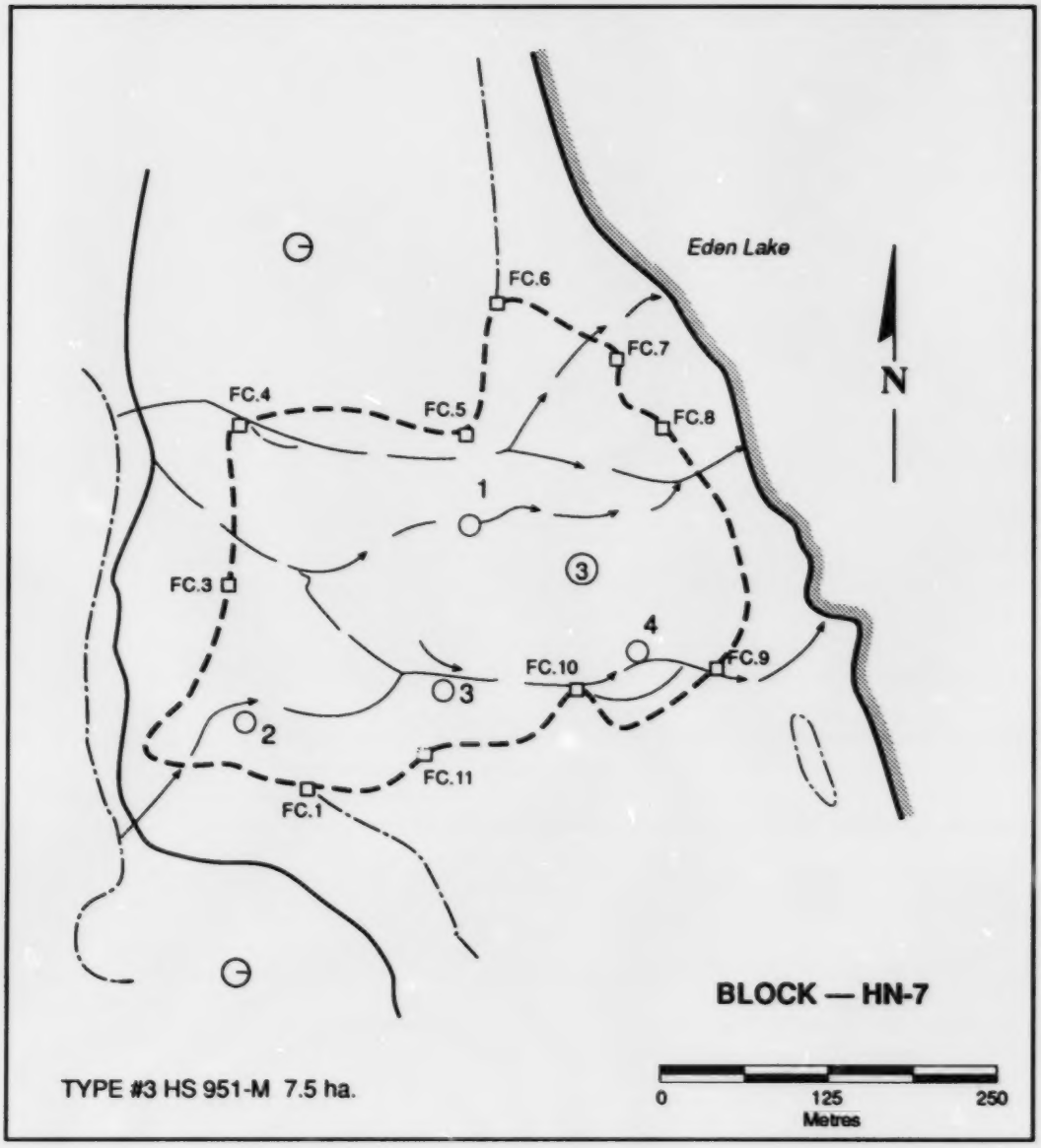

FIGURE 18. Map of case study 3, block HN-7, Eden Lake tributaries. The location of four cruise plots are shown.

TABLE 7. Percentage of stand volume by timber grade in cutblock HN-7, pre- and post-logging. "Peeler/lumber" includes grades A–F, "sawlog" includes grades H–J, and "pulp" includes grades K–Y.

	Total		Spruce		Hemlock		Cedar	
	Pre- %	Post- %	Pre- %	Post- %	Pre- %	Post- %	Pre- %	Post- %
Peeler/lumber	22.4	26.2	48.8	95.4	4.6	4.3	0	0
Sawlog	74.0	69.1	49.9	4.2	90.3	89.6	0	0
Pulp	3.5	4.7	1.3	0.3	5.1	6.2	0	0

TABLE 8. Summary of net merchantable volume per tree in cutblock HN-7, pre- and post-logging

	Total		Spruce		Hemlock		Cedar	
	Pre- (m^3)	Post- (m^3)	Pre- (m^3)	Post- (m^3)	Pre- (m^3)	Post- (m^3)	Pre- (m^3)	Post- (m^3)
Net merch. vol./tree	3.7	1.9	31.3	39.0	2.3	1.4	-	-

The original timber type was HS 951-M. The timber cruise of the area indicated that the net merchantable volume was 1071.2 m^3/ha, of which 60% was hemlock and 40% was spruce. Significantly, spruce composed only 5% of the 293 merchantable stems per hectare in the block, while hemlock composed 95%.

The re-cruise after logging indicates that only 32% of the merchantable stems, but 66% of the net merchantable volume, have been removed by logging. Hemlock composed 88% of the stems removed but only 51% of the volume. Spruce composed only 5% of the stems, but 40% of the volume in the original stand and 49% of the harvested volume.

The remaining stand has 199 merchantable stems per hectare. Hemlock has increased to 99% of the remaining merchantable stems; spruce accounts for only 1%. However, spruce accounts for 24% of the remaining volume.

Grade distribution in the remaining stand has not changed greatly. Originally, 22% were peeler and lumber grade and 74% sawlog. In the remaining stand, 26% are peeler and lumber; 69% are sawlog. The percentage of the spruce volume that is peeler and lumber has actually increased, probably because a few large trees have been left along the two streams.

Post-Logging Assessment

Visual observations after logging indicate that most of the spruce in the stand has been removed by the partial cutting, but large spruce trees have been left near both streams. Most of the remaining trees are hemlock, and tall hemlock with healthy crowns are scattered throughout the block. There is also a vigorous understory of hemlock advance regeneration. Some snags that were not considered hazardous to fallers working in the block remain standing. Others were felled for safety but not yarded because they were not sound. One long narrow patch has been clearcut between the two streams.

As shown in Figure 19, it is difficult to see from a distance that any trees have been removed from the block by the partial cutting. Figure 20 shows the interior of the block after logging.

FIGURE 19. Block HN-7, viewed from nearby road, after partial cutting and helicopter yarding.

FIGURE 20. Block HN-7 after partial cutting and helicopter yarding.

Williams describes the harvest of this block as more closely resembling the classical selection system.[6] The residual trees show a wide range in size and crown position, but many less vigorous stems have also been left. The block that remains is an all-age stand. Further harvest may occur before the usual rotation elapses.[7]

Twenty-one trees remained standing in the four cruise plots after logging. None have blown down and no damage to residual trees was noted. There has been no blowdown in other parts of the block since logging and damage to residual trees is minimal.

Stream habitat protection in this block was excellent. Few trees were felled along the larger streams and the streams and fish habitats appear relatively undisturbed (Figure 21). Many trees, snags, and understory trees remain standing in the riparian areas. There is little slash adjacent to the streams or in locations where it could be moved by floods. Where trees were felled across streams or dry flood channels, helicopter yarding allowed them to be lifted straight up without disturbing the stream banks. Branches and debris that did accumulate in the channel were removed by hand.

No silvicultural surveys or treatments have been done in this block. Field observations indicate that some natural spruce seedlings are established and growing. Fill planting will be possible, particularly in the larger openings.

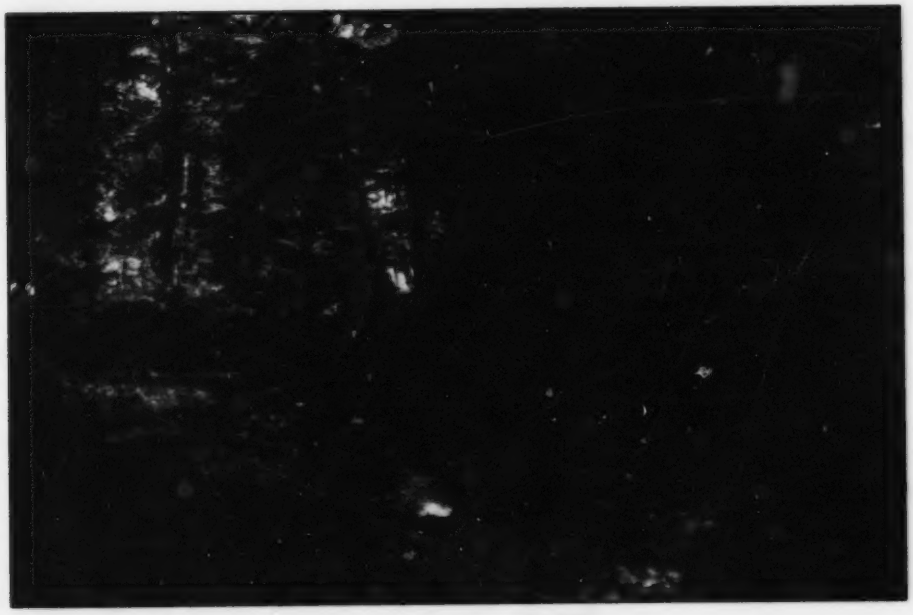

FIGURE 21. Stream in block HN-7 after partial cutting and helicopter yarding.

Waste assessments after logging show that utilization in this block was substantially better than the 35 m^3 of avoidable waste allowed by the Ministry of Forests at the time of logging (R. Volkman, Coast Forest Management Ltd., pers. comm.).

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6 Williams, D.R. 1988. Silvicultural implications and recommendations: helicopter logging on Northwest Graham Island. B.C. Min. For., Queen Charlotte City, B.C. Unpubl. rep. 13 p.

7 B.C. Ministry of Forests. [1988].

This block was different than both HN-1 and HN-7 in original stand composition. A relatively high percentage of the volume was harvested by removing a relatively low percentage of the stems; large trees that were blown down or dying were recovered; and the braided stream channels and fish habitats were well protected. A mixed-age stand with a possibility of future harvest remains, and there is potential for silvicultural treatments to improve the remaining stand.

4.4 Case Study 4: Block H-8, Cave Creek

Description of the Cutting Area

This 7.3-ha cutblock was a narrow fringe of timber along both sides of Cave Creek, bordered by scrub timber. It included two parts that were partially cut on both sides of the stream (Figure 22).

Cave Creek at this location is a 10 m wide Class I stream with low banks and evidence of periodic flooding. There are several 0.5 and 1.0 m wide Class I tributary streams. The Coastal Fisheries-Forestry Guidelines (B.C. Ministry of Forests and Lands *et al.* 1988) and normal streamside management practices on the Queen Charlottes precluded clearcutting both sides of these streams concurrently. The shape and location of the timber in the block prevented conventional logging. For these reasons, the block was approved for partial cutting and yarding by helicopter in 1987.

Timber Volumes, Species, and Grades Removed by Logging

The block was part of a larger cutting permit submission, and pre-logging timber cruise information not available.

Post-Logging Assessment

This block is similar to the other partially cut blocks. Most of it is a light partial cut, on which an all-aged stand with a mix of tree species remains.[8] Numerous tall trees still stand and there is sufficient remaining volume to provide the possibility for a further harvest before the normal rotation elapses.[9,10] Small openings have been created away from the stream channels and the floodplain of Cave Creek. Figure 23 shows the block after logging.

Visually, the main difference in this partially cut block compared to the others is that numerous snags have been left standing. Most snags cannot be jacked or felled in the desired direction and this may create a problem in partial cutting. Falling snags increases the potential for scarring residual trees and increases the number of unmarked trees that must be felled. Falling them also increases slash levels, and inevitably some fall into streams. Safety regulations require that all hazardous snags be felled, but in partially cut blocks fallers must exercise judgement.

A 1-ha area at the base of a slope in the centre of the block was identified during the layout as very wet and shallow rooted. This patch was clearcut to avoid a blowdown problem after partial cutting. Special efforts were made to remove logging debris from two small streams in this area and the stream banks were seeded with grass after logging.

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8 B.C. Ministry of Forests. [1988].
9 Ibid.
10 Jablanczy, [1988].

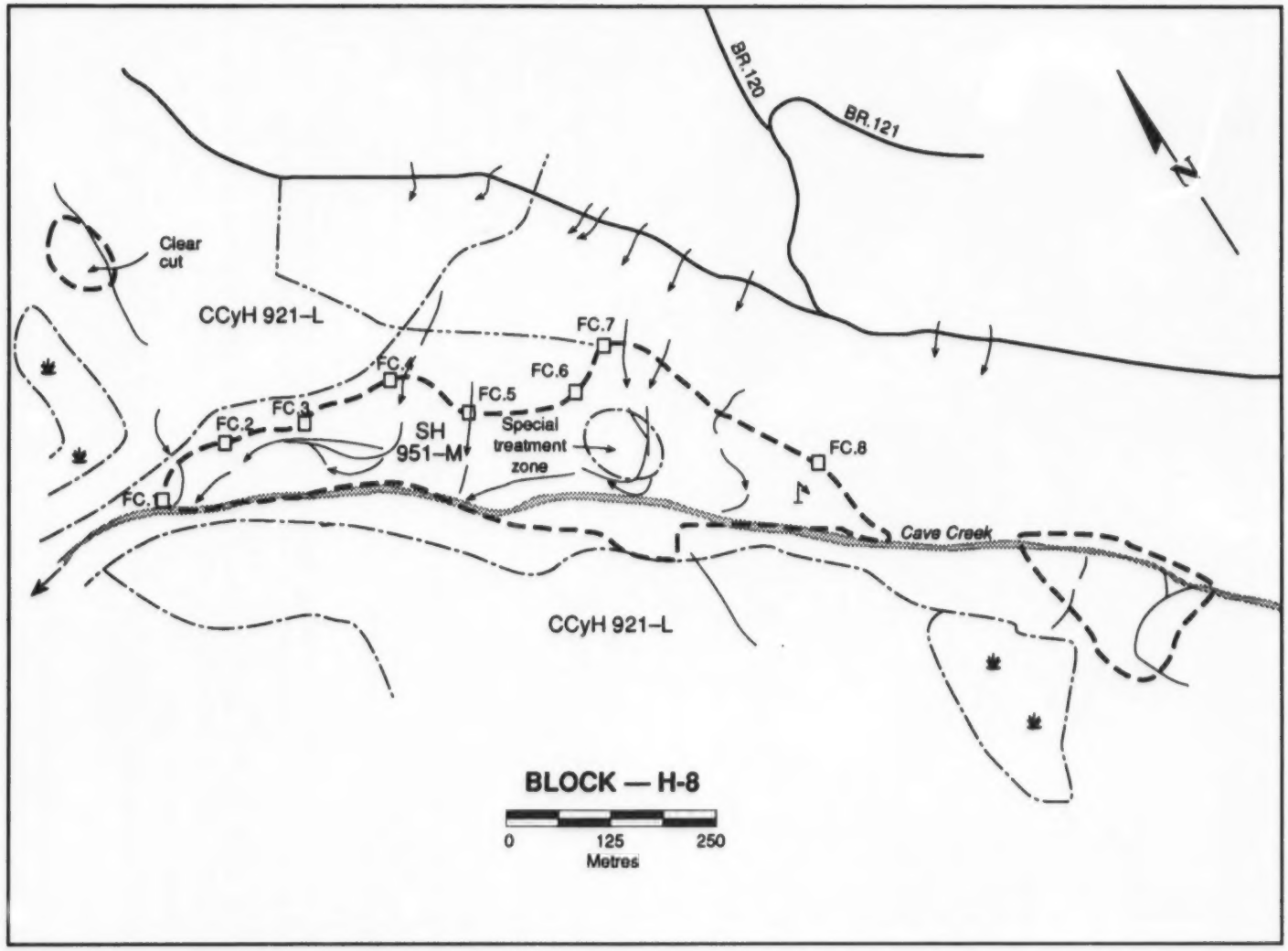

FIGURE 22. Map of case study 4, block H-8, Cave Creek.

FIGURE 23. Block H-8 after partial cutting and helicopter yarding.

Since logging, some further blowdown of small diameter hemlock has occurred in the partially cut stand around the clearcut opening and near one of the small streams. The blowdown involves a small percentage of the trees left after partial cutting.

In the partially cut parts of the block, streams appear undisturbed by logging. Although trees have been removed from both sides of Cave Creek, few have been removed from the stream banks or adjacent areas prone to flooding. The banks appear to be undisturbed, and there is very little logging slash close to the stream where it could be moved into the stream channel by floodwaters.

Very little scarring of residual trees is evident in the block, but no silvicultural surveys or treatments have taken place in this block to date.

5 DISCUSSION

Standish (1989) identified and ranked the constraints that have limited partial cutting in the coastal old-growth forests of British Columbia as follows:

1. damage to residual trees;
2. lack of suitable yarding equipment;
3. logger's safety;
4. inadequate quality or quantity of regeneration;
5. windfall of residual trees;

6. lack of skilled foresters and technologists; and

7. lack of skilled loggers.

The case studies described here and the experience in Naden Harbour since 1986 show that most of these constraints have been overcome. Husby Forest Products Ltd. has found that partial cutting and helicopter logging can be a technically feasible, safe and economical method of logging on environmentally sensitive streamside and floodplain sites (R. Torney, Husby Forest Products Ltd., pers. comm.).

The technical problems identified by Standish (1989), Nelson *et al.* (1990), and Sanders and Wilford (1986) have been largely overcome by the use of the S 64-E Sky-Crane, the development of an intensive system of logging layout and tree marking, and an experienced work force.

The objectives of causing minimal disturbance to the stream environment have been met by judicious falling practices, helicopter yarding, and stream clean-up. As well as protecting fish habitats, partial cutting has retained some of the biological and structural diversity of the forests. It also appears to contribute to the protection of the wildlife habitats of various birds and mammals contained in the streamside and floodplain areas.

The remaining major concerns about partial cutting are that it can lead to extensive blowdown, widespread damage to residual trees, and excessive amounts of waste. It is also believed to create a number of silvicultural problems. These issues are discussed below.

5.1 Blowdown of Residual Trees

After 4 years of partial cutting in 14 geographically separated cutblocks, blowdown of the residual trees in partially cut blocks does not appear to be a major problem at Naden Harbour. Considerable blowdown did occur immediately after logging in two blocks logged in 1986, and there was a minor amount in one other block logged in 1986. Overall, however, most of the partially cut blocks logged in 1986 and 1987 suffered minimal blowdown. In the 13 cruise plots resurveyed in the case studies, only 3 of the 66 trees left after logging have blown down.

Most of these trees appeared to be tall, medium diameter trees, previously protected from the wind by the larger trees that formed the canopy before logging. The block in which the most blowdown occurred was the wettest of the floodplain sites logged in 1986. Its exposed location and shallow rooting combined to make blowdown so prevalent.

Some of the blowdown in the three blocks occurred along previously clearcut boundaries and may have occurred even if the stands had not been partially cut. However, removal of the large trees did appear to extend blowdown further into the stand than would have been expected had it not been partially cut.

Since 1986, the objectives for partial cutting and the marking procedures for falling have been adjusted (Appendix 2). Fewer trees, representing a greater range of tree diameters, are now removed, and more large, tall, windfirm trees in the original canopy are left. The stand is less open and patch cuts and small clearcuts within partially cut blocks are kept very small. As noted in the H-8 case study, wet or poorly drained areas with shallow tree rooting are planned for patch cutting or left and protected with surrounding trees.

Since very little blowdown has occurred in the four case studies or in any of the recently cut blocks, these adjustments appear to have greatly reduced the risk of blowdown.

5.2 Damage to Residual Trees

Some damage to residual trees has been caused by falling and yarding during the 4 years of partial cutting and yarding by helicopter. Most of this damage, however, is related to specific local circumstances. Overall, damage to residual trees was not a widespread problem in blocks that were helicopter yarded in 1986 and 1987.

Scarring of residual trees in these case studies is largely related to the number of trees felled. Partial cuts that remove a large number of stems or a higher percentage of the volume appear to cause more residual damage than cuts that remove fewer stems. Some damage to residual trees also resulted from the 1986 marking procedure which required trees to be felled into a central patch to increase the efficiency of helicopter yarding.

The current partial cutting objectives and tree marking procedures have reduced the damage to residual trees, by calling for light partial or small patch cuts, and by allowing the faller more flexibility in choosing the direction in which to fall trees. Use of the S 64-E helicopter, with its great lifting capability, also appears to be important in minimizing damage to residual trees.

In the most recently logged partially cut block, HN-1, very little damage to residual trees has occurred.

5.3 Utilization Levels and Slash Accumulations

The waste assessment information available for the Naden Harbour helicopter blocks indicates that wood utilization has been generally high. The helicopter cutting permit, which included all the blocks yarded by helicopter on F.L. A-16869 in 1986, had the highest recovery of any permit sampled.

The four blocks described in the case studies also had comparable or better recoveries than did conventional blocks logged at the same time (R. Volkman, Coast Forest Management Ltd., pers. comm.). These high recoveries may partly reflect the much lower incidence of broken logs that occurs with helicopter yarding compared to conventional non-aerial cable yarding systems.

Visually, however, slash levels often appear high in partially cut blocks because tops and limbs are not crushed or broken in the yarding process. The high, loose slash is a minor impediment to walking and could inhibit planting operations and the growth of regeneration. In many parts of the partially cut blocks, few trees have been removed, so the forest floor is relatively undisturbed and slash is widely dispersed.

5.4 Silvicultural Concerns

In a 1988 review of the Husby Forest Products Ltd. operations at Naden Harbour, Williams (1988) concluded that silviculture had been a secondary consideration of partial cutting.[11] The cutting that had taken place was not planned to fit into either of the classical silvicultural systems — selection or shelterwood. Certain blocks had turned out to approximate these systems, but there had not been a plan or schedule for repeated entries into the stand.

Partial cutting on these sites was originally conceived to meet the objectives of removing timber while protecting the sensitive and important fish habitat values of the floodplain sites from the impacts of conventional clearcutting. These objectives took precedence over the silvicultural considerations, though the latter were not ignored or unduly compromised (D. Corrin, Malaspina College, pers comm.).

Williams (1988) concluded that, while many good quality, vigorous trees had been left in the partially cut blocks, many blocks also required some corrective cutting to achieve a satisfactory condition.[12] He identified problems with residual tree quality, density, and windfirmness, and expressed concerns that the poor quality residual trees would not add increment.

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[11] Williams, 1988.
[12] Ibid.

Residual trees may also inhibit regeneration. By maintaining a shaded environment, they slow the growth of Sitka spruce and tend to favour western hemlock on sites best suited to spruce. Infected hemlock residuals spread mistletoe to understory trees and new regeneration.

To date, the silvicultural implications of the partial cutting at Naden Harbour have not been thoroughly assessed. There is not even a standard methodology for assessing partially cut blocks in coastal forests and regeneration surveys have not been carried out. Nevertheless, some general comments can be made.

First, partial cutting can be silviculturally feasible in coastal hemlock/spruce forests, although growth rates of trees may be relatively slow (Farr and Harris 1971; Williamson and Ruth 1976; Standish 1989). According to Sanders and Wilford (1986), the feasibility depends on many site-specific factors. At Naden Harbour, some of the partially cut blocks have shown that good quality, vigorous residual trees and advance regeneration can be left. These partial cuts are expected to be windfirm and will become fully stocked, uneven-aged stands that will support another harvest before rotation. In the HN-1 block, the remaining stand closely approximates the original stand and contains a good mix of species, age classes, tree heights, and advance regeneration. With natural regeneration and fill planting, it will become a fully stocked uneven-aged stand that will support another harvest.

Second, partial cuts in these blocks can be improved by silvicultural treatments that remove damaged or poor quality residual stems, space advanced regeneration, and plant seedlings under openings in the canopy. For example, as well as retaining good quality, mature, residual trees after partial cutting, the type of treatments undertaken in the HN-5 block can be used to achieve a fully stocked mixed species, multi-aged stand.

Where sufficiently large openings have been created by partial cutting, Sitka spruce could be planted and expected to grow. Taylor (1990) points out that Sitka spruce regenerates naturally under gaps in the canopy of coastal forests, and suggests that openings of 800–1000 m^2 are sufficient.

Third, silvicultural objectives can be developed for all blocks scheduled for partial cutting. These objectives should be incorporated in the layout procedures and carried out in the post-logging phase. A schedule for future harvests should be included. Stand and stock tables will have to be developed to guide the marking of trees for harvest. With the great flexibility provided by the S 64-E Sky-Crane, almost any mix of species, heights and diameter classes can be left in the residual stand once silvicultural objectives were specified.

Finally, and most importantly, the silvicultural objectives must not be considered in isolation. Meeting other forest management objectives, such as protection of fish habitat, wildlife or landscape management may require that silvicultural objectives be modified. In particular, the normal coastal silvicultural objective of replacing an uneven-age, old-growth stand with an even-age stand of preferred commercial species that are free growing in a given number of years should be modified if other important management objectives require, or favour, partial cutting. Acceptance of slower growth rates or higher silvicultural costs in partially cut blocks may be necessary to meet the other management requirements.

6 CONCLUSIONS

At Naden Harbour, partial cutting and helicopter yarding has been a successful method of removing timber from environmentally sensitive streamside and floodplain blocks. On these sites, it is an economically viable and technically feasible operation. There has been virtually no disturbance of stream banks or introduction of logging debris. Large trees and understory vegetation remain along the stream edges, and slash accumulations are much smaller and farther from the stream edge than would have resulted from clearcutting.

The methods of selecting blocks and marking trees and the procedures of falling, helicopter yarding, and post-logging clean-up developed at Naden Harbour appear to be applicable to a wide range of situations in other areas in coastal British Columbia.

Problems with blowdown and scarring of residual trees were resolved once the procedure for marking trees was revised. The current procedure is to mark 15–25% of the volume of the stand, and then to give fallers flexibility in determining the direction in which trees are felled and an option to fall trees that are unsafe. The stated objective is to remove approximately 30% of the volume of the stand, leaving a proportional representation of the species and diameter classes in the original stand. Experience at Naden Harbour has shown that marking less than that volume and providing the fallers with some choice enables that objective to be met.

As well as changes to the marking procedure, several other modifications will be needed to ensure the successful application of this approach to coastal harvesting:

- Partial cutting and helicopter yarding on environmentally sensitive sites require a more elaborate engineering and layout procedure than conventional clearcut logging and cable yarding. Husby Forest Products Ltd. and the government agencies involved at Naden Harbour have found that having an on-site environmental technician is important in ensuring that the environmental requirements are identified at the earliest planning stage and met in all phases of the logging operation. Close and continual communication between engineering staff, fallers, and rigging crews is essential.
- Future silvicultural considerations may require that stand and stock tables be developed for each block so that trees can be marked in accordance with a specified silvicultural objective for the residual stand. This will require that current cruising procedures be modified, and that trees smaller than 17.5 cm in diameter also be measured during the cruise.
- Silvicultural objectives and post-logging silvicultural treatments in the partial cut blocks will be more complex than in blocks that are clearcut and yarded by more conventional methods. On environmentally sensitive sites where partial cutting can protect important non-timber forest resources, modification of silvicultural objectives, application of new types of silvicultural treatments, and acceptance of higher costs incurred in these more elaborate treatments will be necessary.

Research is also required. This retrospective study has had to rely on qualitative assessments and intuitive judgement to evaluate the implications of partial cutting and helicopter yarding on these environmentally sensitive sites. More rigorous evaluations of these methods will require better information on the pre-logging stand conditions, better measures to evaluate the protection of fish habitats, and better knowledge of the response of advance regeneration and planted trees to the shaded environments in partially cut stands.

7 LITERATURE CITED

B.C. Ministry of Forests. 1990 Operational cruising requirements in the Vancouver Region. Vancouver Region Circular Letter VR90-541, Jan. 17, 1990.

B.C. Ministry of Forests, B.C. Ministry of Environment, Canada Department of Fisheries and Oceans, Council of Forest Industries. 1988. British Columbia coastal fisheries-forestry guidelines. 2nd ed. Victoria, B.C.

B.C. Ministry of Forests and Lands. 1988. Biogeoclimatic and ecoregion units of the Prince Rupert Forest Region. Map prepared by Res. Branch, Victoria, B.C.

Banner, A. and J. Pojar. 1987. Ecosystem classification of the Coastal Western Hemlock Zone, hypermaritime subzone (CWHhm) within the Mid Coast, North Coast and Queen Charlotte Islands Timber Supply Areas. B.C. Min. For. Lands, Smithers, B.C.

Brown, T.G. 1985. The role of abandoned stream channels as over-wintering habitat for juvenile salmonids. M.Sc. thesis. Univ. B.C., Vancouver, B.C.

Bustard, D.R. and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon. J. Fish. Res. Board Can. 32:667–680.

Farr, W.A. and A.S. Harris. 1971. Partial cutting of western hemlock and Sitka spruce in Southeast Alaska. U.S. Dep. Agric. For. Serv. Res. Pap. PNW-124.

Ford-Robertson, F.C. 1971. Terminology of forest science, technology practice and products. Soc. Am. For., Washington, D.C. The Multilingual Forestry Terminology Series No. 1.

Hartman, G.F. 1987. Some preliminary comments on results of studies of trout biology and logging impacts in Carnation Creek. *In* Proc. Workshop on Applying 15 years of Carnation Creek Results. T.W. Chamberlin (editor). Pac. Biolog. Sta., Nanaimo, B.C., pp. 175–180.

Hartman, G.F. and T.G. Brown. 1987. The use of small temporary, floodplain tributaries by juvenile salmonids in a west coast rain-forest drainage basin, Carnation Creek, British Columbia. Can. J. Fish. Aquatic Sci. 44:262–270.

Hatfield, H.R. 1988. Clearcut versus selection. For. Plan. Can. 4(4):9–10.

Johnson, D. 1988. Heli-logging. Timber Trades J. June 4, 1988, pp. 13–14.

Nelson, J., D. Daust, and S. Finn. 1990. A review of silvicultural systems and harvesting alternatives for old-growth forests of coastal British Columbia. Rep. prepared for MacMillan Bloedel Ltd., Woodland Services, Nanaimo, B.C.

Sanders, P.R.W. and D.J. Wilford. 1986. Silvicultural alternatives for the management of unstable sites in the Queen Charlotte Islands: a literature review and recommendations. B.C. Min. For., Victoria, B.C. Land Manage. Rep. 42.

Standish, J.T. 1989. Alternative silvicultural systems for streamside management zones and steep slopes in coastal British Columbia: recommendations based on an opinion survey and field observations. Rep. prepared for B.C. Min. For., Vancouver Region, Burnaby, B.C.

Taylor, A.H. 1990. Disturbance and persistence of Sitka spruce (*Picea sitchensis* (Bong) Carr.) in coastal forests of the Pacific Northwest, North America. J. Biogeography (1990) 17:47–58.

Toews, D.A.A. and M.K. Moore. 1982. The effects of three streamside logging treatments on organic debris and channel morphology of Carnation Creek. *In* Proc. Carnation Creek Workshop: A 10-Year Review. G.F. Hartman (editor). Pac. Biolog. Sta., Nanaimo, B.C., pp. 129–153.

Townshend, R.B. 1981. Geotechnic report: Davidson, Cave and Haines Creeks, Queen Charlotte Islands. Rep. prepared for CIPA Industries, Vancouver, B.C. by Peril Bay Geotechnic Services, Nanaimo, B.C.

Williamson, R.L. and R.H. Ruth. 1976. Results of shelterwood cutting in western hemlock. U.S. Dep. Agric. For. Serv. Res. Pap. PNW-210.

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APPENDIX 1. Definitions of partial cutting

The helicopter logging on sensitive streamside and floodplain sites at Naden Harbour removes individual marked trees or groups of trees from an uneven-age forest stand. The trees removed include a range of species, heights and diameters, and log grades. An uneven-age stand of mixed species, heights, and diameters is left after logging.

"Selective logging" is the term commonly used to describe this type of logging. In silvicultural terminology, however, selective logging is defined as:

> a type of exploitation cutting that removes only certain species above a certain size or of high value, with known silvicultural requirements and/or sustained yields being wholly or largely ignored or found impossible to fulfill (Ford-Robertson 1971).

In British Columbia, the term selective logging is usually associated with "highgrading" or "creaming," which have negative connotations to foresters. Thus, this terminology causes considerable controversy. It also does not accurately describe the logging at Naden Harbour.

A more appropriate term might be "selection cutting." This silvicultural system has a wide variety of interpretations but is defined as:

> the annual or periodic removal of trees (particularly mature trees) individually or in small groups from an uneven-age forest in order to realize the yield and establish a new crop of uneven age distribution (Ford-Robertson 1971).

The "selection system" is defined as:

> an uneven-age silvicultural system in which trees are removed individually, here and there, from a large area each year (Ford-Robertson 1971).

The logging at Naden Harbour does meet some of these criteria. Trees are removed individually or in small groups from an uneven-age forest, and an uneven-age forest remains after logging. However, silviculturists argue that since trees are not being removed periodically and a schedule for further entries into the stand has not been determined, "selection cutting" is not an appropriate term.

Williams (1988), in a silvicultural review of the Naden Harbour operations, states that the cutting in some blocks resembles the single tree or group selection system (leading to an uneven-age stand), and in other blocks a shelterwood system (leading to an even-age stand).[1] He proposes the use of "partial cutting" as the most appropriate terminology. Partial cutting is defined as:

> "tree removal other than clearcutting, i.e., taking only part of the stand" (Ford-Robertson 1971).

Partial cutting is used throughout this report to describe the Naden Harbour operations. It accurately describes the removal of individual trees or groups of trees that are marked for cutting, from an uneven-age, old-growth forest. The number, species, height, and grade distribution of trees removed and left in each of the partially cut blocks varies with the harvesting and silvicultural objectives, the composition of the stand, its economic value, and the physical features of the site.

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[1] Williams, D.R. 1988. Silvicultural implications and recommendations: helicopter logging on Northwest Graham Island. B.C. Min. For., Queen Charlotte City, B.C. Unpubl. rep. 13 p.

APPENDIX 2. Procedures for partial cutting and helicopter yarding on environmentally sensitive floodplain sites

Partial cutting and yarding with helicopters require an intensive effort during all phases of logging. Husby Forest Products Ltd. uses a forestry consulting company, Coast Forest Management Ltd., to do all the field engineering and logging planning work. They use their own supervisory staff and logging crews for the actual logging operations. Falling is done by a falling contractor. In addition, Husby Forest Products Ltd. employs an environmental technician, who is on-site through all phases of layout, falling, yarding, and post-logging clean-up to ensure that the sensitive environmental features of the floodplain and streamside sites are protected.

Over the 4-year period, the following procedures for partial cutting and helicopter yarding have been developed by Husby and Coast in co-operation with the ministries of Forests and Environment and the Department of Fisheries and Oceans.

Engineering and Layout

Areas suitable for helicopter logging are initially identified on a map. Often, these are areas where previous applications have been turned down by the Ministry of Forests because of the anticipated environmental impacts of conventional clearcutting and cable yarding on fish habitat. The forest engineers and environmental technician walk through the areas identified as potential sites for partial cutting and examine both the environmental sensitivity and the physical and economic suitability. If suitable, the proposed block is scheduled for partial cutting and entered on a 5-year development plan for review by government agencies.

The government review usually involves a field inspection of the proposed area. The Ministry of Forests prefers that all blocks be clearcut to maximize timber production and to meet silvicultural objectives. Thus, the field review focusses on the environmental sensitivity of the area and the need for partial cutting and helicopter yarding. The Ministry will only approve partial cutting if conventional harvesting methods are not acceptable. This assessment of the need for partial cutting is provided by the Department of Fisheries and Oceans or the Ministry of Environment, with advice from the logging engineers and the company's environmental technician, and is reviewed by the Ministry of Forests.

If approval in principle for partial cutting is received from the government agencies, the detailed logging layout begins with field engineers and the environmental technician working together.

All of the streams in the proposed block, including dry channels and intermittent streams, are flagged, traversed, and mapped. The presence of fish in the streams is determined by minnow trapping and streams are classified according to the British Columbia Coastal Fisheries-Forestry Guidelines (B.C. Ministry of Forests *et al.* 1988) (Appendix 3). The stream classification determines the type of falling prescriptions required to protect the fish habitat values identified. Stream classifications and the appropriate falling and yarding prescriptions are indicated in the field by the colour of ribbon used to mark each channel.

The block boundaries for partial cutting are also established. Areas within the block which could be clearcut or patch cut without compromising the environmental sensitivity are identified. The effect of clearcutting on the windfirmness of the partial cut areas is considered. Areas within the block where there should be no cutting, because of flooding or other reasons, are identified and excluded from the block.

The volume of timber in the proposed block is determined by conventional timber cruising methods.

Streamside Logging Prescriptions

Streamside logging prescriptions within the proposed cutblock are based on the Coastal Fisheries-Forestry Guidelines (B.C. Ministry of Forests *et al.* 1988) and the local experience on similar sites. Husby Forest Products Ltd. has developed its own set of guidelines for partial cutting and yarding by helicopter near streamsides (Appendix 4).

As defined in the Coastal Fisheries-Forestry Guidelines, Class I and II streams are low gradient streams (usually less than 12%) with anadromous or resident sport fish present on-site. This classification includes all side channels, back water areas, and even seasonally dry channels on the floodplain which may provide fish habitat in the winter. These streams are given maximum protection. In conventional clearcut areas, this normally means that no trees are allowed to be felled or yarded into or across streams channels.

In partially cut and helicopter yarded blocks, this is also the basic objective for Class I and II streams. However, because partial cutting and helicopter yarding reduce the number of trees felled and greatly reduce the stream bank disturbance from yarding, some individual trees are permitted to be felled directly across small Class I and II streams where bank configuration and terrain features allow. These trees are carefully considered and the number is minimized.

Class III and IV streams are steeper gradient streams (usually greater than 8%) with small resident non-sport fish or no fish present (B.C. Ministry of Forests *et al.* 1988) (Appendix 3). They are commonly referred to as "water quality" streams. The management objective for these streams is to prevent transport of sediment and debris to Class I and II streams downstream, so Class III and IV streams generally receive less protection. Cross-stream falling and yarding is allowed if it will not affect Class I and II streams downstream. However, Class III and IV streams are uncommon on the floodplains where partial cutting has occurred.

Tree Marking

Marking of individual trees to be felled is an essential feature of partial cutting in old-growth coastal forests. It reflects the objectives set for the logging operation and determines the species, height, and age class structure of the remaining stand.

After block boundaries for partial cutting are established and basic streamside prescriptions determined, individual trees are marked by the field engineers and environmental technician. Spray paint marks are used both to identify the trees to be cut and to indicate the direction each tree is to be felled.

The approach to marking trees has changed as experience with partial cutting has been gained. In the first 2 years of partial cutting, 1986 and 1987, the objective of partial cutting was to remove a substantial percentage of the timber volume while protecting fish habitats and leaving the canopy largely intact. Thus, the largest and best trees in the stand were marked and removed except where those trees could not be removed without affecting fish habitat. Subsequent review of the results prompted a revision of these marking procedures. Concerns were expressed about the size of some of the openings that were created by removing patches of large trees, and about the timber quality and volume in the remaining stands.

In 1988 and 1989, new objectives were set. In general, these were to protect fish habitats and sensitive sites, maintain an intact canopy, and leave a stand with well-distributed, large, good quality trees. The specific objective in marking trees for cutting was to harvest approximately 30% of the standing volume in the block and to distribute this harvest over the range of species and diameter classes in the stand. These are the objectives currently used for tree marking.

The system by which the field engineers mark the direction in which a tree is to be felled has also changed. In 1986 and 1987, a single O was painted on a tree to indicate the direction that it was to be felled and a series of X's were painted on all other sides of the tree to indicate that the tree was not to be felled in those directions. Engineers painting the trees marked them to make sure they were felled away from streams and sensitive areas. Trees were also marked to be felled in directions that would create a pile of logs for easy yarding by the helicopter. However, it proved impossible for the engineers to predict the direction each tree would fall, and some trees could not be felled in the direction that was marked. Falling trees into groups resulted in numerous damaged residual trees and did not assist greatly in helicopter yarding. Thus, this system of marking was abandoned in 1987.

Since 1988, the practice for marking in partially cut areas has been to mark both X's and O's on trees. The X's indicate to the faller the directions the tree is not to be felled, based on the location of streams and sensitive sites. The O's give the faller a range of acceptable directions. In this system, the faller decides which direction to fall a tree from the options indicated. He is instructed to leave the tree if it can only be felled in an X direction or if he feels that it will cause damage to residual trees or require that nearby snags be felled for safety reasons.

With these general objectives and procedures for tree marking, several important factors determine which individual trees are marked.

First, the safety of the fallers is of paramount concern. If the marking crew feels that a tree cannot be felled safely in a required direction, it is not marked. The marking crew is also aware that safe working conditions will require a faller to fall unmarked trees in order to safely fall the marked ones. However, if they will enter streams or cause damage to the floodplain when felled, the original trees are left unmarked.

The marking process must also consider the additional trees that will be felled for safety reasons, and marking density has to be adjusted to ensure that the stand density after falling is consistent with the original objective.

The number of incidental trees that are felled for safety reasons increases with the number of marked trees being felled. Experience has shown that, in lightly marked stands, the total number of trees felled will be approximately twice the number originally marked, but this varies by stand. Usually the incidental trees are smaller and poorer quality trees. A relatively low percentage of the trees is therefore marked.

A third consideration in marking is the blowdown and damage to residual trees that may occur during and after logging. Experience at Naden Harbour has shown that less damage and blowdown occur when fewer trees are marked and removed.

The current procedures for marking trees reflect these considerations for safety, residual damage, and blowdown. To meet the objective of removing approximately 30% of the volume, approximately 15–25% of the merchantable volume in the block is marked and this is distributed over the range of species and diameters.

Finally, protection of streams and the avoidance of damage to residual trees and advance regeneration are major considerations in the marking of individual trees. In general, only those trees that can be safely felled away from Class I and II streams and the floodplain areas are marked for falling. Some trees are marked for falling directly across Class III and IV streams if no bank damage will result. In general, leaning trees near streams and trees that would damage unmarked trees or patches of advanced regeneration are not marked.

Some trees are marked with a painted ring around the trunk and painted SV or SUPERVISOR. This indicates to the faller that the tree should not be felled without consultation with a supervisor. This marking ensures adherence to specific company or government falling prescriptions. For example, if a tree marked SV cannot be felled in a certain direction or a particular way, the supervisor will advise that it should be left standing. If a leaning tree is identified for falling across a stream and has been approved by government agencies, it is marked SV and the supervisor outlines the requirements to the faller at the time of falling.

Cutting Permit Submission and Review

After trees are marked in the field, a 1:5000 cutting permit map is prepared. This map accurately shows all streams, identifies the location of all SV trees, and notes any special treatment areas.

The cutting permit map is accompanied by a written text describing the logging plan and is submitted to the Ministry of Forests for approval. The results of fry trapping or observations of fish in the streams are included.

Most partial cut blocks are reviewed in the field by the Department of Fisheries and Oceans and the Ministry of Environment. After the field reviews and before approval, these agencies or the Ministry of Forests can request changes ranging from the amending of the boundaries of the block to the changing of the proposed falling direction of an individual tree.

Falling

Once a Cutting Permit is approved by the Ministry of Forests, falling can begin.

The faller's task in partial cutting is to fall the marked trees in the direction indicated. He is instructed to minimize the number of unmarked trees that are felled and to minimize damage to unmarked trees.

The faller's primary consideration in these situations is safety. All unsafe snags are felled to protect falling and yarding crews but an effort is made to leave snags standing. The faller's second priority is the protection of fish habitat. As noted in the company's guidelines for fish habitat protection (Appendix 4), protection of fish habitat takes precedence over timber harvesting. The third priority is timber production.

With these considerations, the fallers make decisions and fall the marked trees in the indicated directions as much as possible. Decisions are made jointly with the field engineers and the environmental technician who are also on site during falling.

If the faller feels that he cannot fall the tree in the direction indicated, the tree is usually left. If removal of a marked tree requires the falling of a snag into or near a stream, or if falling a marked tree will damage a leave tree or patch of residuals, the faller can decide to leave the tree or to fall it in another direction.

Many trees are left for experienced falling supervisors. The trees marked SUPERVISOR are generally felled last. Hydraulic jacks are used frequently to ensure that the direction of fall is consistent with the painted marks. In the end, most marked trees are felled and most unmarked trees are left standing.

Trees are limbed as in a normal operation, but bucked according to length and weight. The faller uses a weight card, which shows weights of logs based on species, log length, and mid-diameter to determine optimal log length and weight.

Exceptions are made for any trees that are felled close to or across streams. Generally, they are not limbed or topped so that all branches and tops can be yarded away from the streamside by the helicopter. However, if limbs are actually in the stream they are immediately removed by the faller or the environmental technician. Trees that have been felled across Class I and II streams are usually not bucked so that they will stay suspended above the soft stream banks and minimize ground disturbance. If the trees are too heavy for the helicopter to lift, they are bucked at the time of yarding.

Helicopter Yarding

Speed and precision are essential parts of the helicopter yarding operation. The machine lifts a "turn" of logs approximately every 2 minutes. Thus, all plans to protect sensitive sites must be in place before the helicopter yarding begins.

Before helicopter yarding, steel chokers are placed around each log by a crew of chokermen. Another crewman, called a striprunner, gathers several choker ends together to create a "turn," or group of logs that are to be lifted by the helicopter. The turn is based on weight and logs are grouped together so that their total weight is as close as possible to the maximum allowable payload of the helicopter. The striprunners estimate the weights of individual choked logs based on the diameter and length, knowing that a faller has bucked the log to a certain length using the weight card.

The weight of each turn is checked by a third crewman, a hooker, who also makes sure that chokers are free of hang ups.

Turn weight is a very important factor in the operation. If the weight of the turn exceeds the maximum payload of the helicopter, the logs must be aborted by the pilots. But the high operating costs of the helicopter require that turn weights be as close as possible to the maximum available payload. The target efficiency is to average within 85% of the maximum available payload. The average turn weighs about 7050 kg (15 500 lb) and is about 8 m^3 in volume. The heaviest turns are saved for the end of a shift when fuel weight is low and the lifting capacity is, therefore, the greatest.

With the helicopter hovering overhead, the ground crew attaches the chokers to two specially designed hooks suspended on a long cable below the helicopter. The turn is then lifted straight up and out of the standing trees and flown to a nearby road. At the roadside, the helicopter lowers the logs to the ground and the chokers are released from the hooks electronically by the pilot.

Any limbs and tops attached to logs are removed on the roadside. The logs are sorted and stacked by a hydraulic log loader, and then loaded on logging trucks at a later date for transport to a dry land sort. No logs are dropped from the helicopter into water in the Naden Harbour operations.

Sensitive sites prone to flooding are flagged with coloured ribbon after falling and just before helicopter yarding. Tops, limbs, fallen snags, and debris piles are marked and flown out of these areas by the helicopter. This material is dropped into the adjacent slash. In most cases, sensitive sites have been identified before falling and bucking, so limbs and tops are left on the logs and flown to the roadside to be removed from the logs.

Instructions can be painted on logs to indicate where chokers should be attached. These logs can be lifted up from one end to reduce any ground disturbance.

Roadside landing areas occupy a large area and are a special concern. Before yarding, stumps on the roadside are painted to identify locations where logs should not be dropped by the helicopter or stacked by the loader.

One large service landing is constructed for refueling and servicing the helicopter. This site is chosen to be distant from streams. A fuel line is attached directly from a fuel tanker to the helicopter to prevent spillage of fuel. Waste oil is tested in a commercial laboratory and, if it passes Ministry of Environment standards, is used for dust control on the landing.

Post-Logging Clean-up

During helicopter yarding, or soon after it is completed, a stream-cleaning contractor is retained. The environmental technician supervises the removal of all branches introduced into streams by falling or by the helicopter rotor wash during yarding. Breakage of branches and tops from streamside alder trees by rotor wash is a particular problem.

Generally, a three-person crew with two chainsaws and a long-handled four-pronged rake removes branches that are thrown above the high water mark or placed on stumps. Most of the work is done by hand. All natural pre-logging in-stream debris and all solid material suspended above the channel is left in place. Natural stream blockages are left undisturbed. The objective is to remove only the material placed in the stream by the logging.

APPENDIX 3. Stream classification in the Coastal Fisheries-Forestry Guidelines

Class I

Anadromous salmonids or moderate to high levels of resident sports fish are present, or the reach has been identified for upgrading in an approved fisheries management plan. Stream gradient is usually less than 8%. The objective is to maintain productive capacity of the fish habitats including water quality and stream channel characteristics. To provide flexibility, it may be necessary to design compensating or mitigating measures that offset the unavoidable effects which even careful forest harvesting may have on a stream system.

Class II

Low levels of resident sports fish are present. Stream gradient is usually 8–12%. The objective is to minimize loss of productive capacity of the fish habitats and maintain sufficient channel integrity to protect Class I reaches from accelerated transport of sediment or debris.

Class III

Resident non-sport fish are present. Stream gradient is usually 8–12%. The objective is to maintain the genetic stock of indigenous species and maintain sufficient stream channel integrity to protect Class I and Class II reaches which may be affected by accelerated transport of sediment or debris.

Class IV

No fish are present and stream gradient is usually greater than 20%. The objective is to maintain sufficient stream channel integrity to protect Class I and Class II reaches which may be affected by accelerated transport of sediment or debris.

APPENDIX 4. Husby Forest Products Ltd. special treatments for helicopter logging, (March 1988)

General

Husby Forest Products Ltd. will develop site-specific stream, soil, and timber protective measures in conjunction with the Land Use Planning Advisory Team (LUPAT). These will be discussed with all agencies involved and modified where necessary. Once a set of prescriptions is agreed to, Husby Forest Products Ltd. will supply on-site monitoring and supervision of operations during harvesting. This will take place at the engineering, falling and yarding phases independently.

On floodplains and streamsides, protection of fish habitat will be given the highest priority.

Should any material enter streams inadvertently during harvesting, it will be removed immediately.

Engineering Treatments

1. Mark all streams *away from which trees are to be felled and yarded* within cutblocks, using "red candy-striped and hi-viz pink" ribbon. If a creek or river is used as a boundary, then hang "red candy-striped" ribbon, along with "orange-glow" ribbon.
2. Mark all streams *away from which trees are to be felled and yarded where possible* within cutblocks, using "blue candy-striped" ribbon. If a stream is used as a boundary, then hang "blue candy-striped" ribbon along with "orange-glow" ribbon.
3. Mark all clearcut boundaries with "orange-glow" ribbon.
4. Mark all areas of special falling procedures with splitline boundaries in "orange-glow" ribbon (e.g., lodgepole pine strip areas along creeks). If excessive debris is a problem, such as on a floodplain, designate the area as a special treatment zone and ribbon it in "lime-glow" ribbon.
5. Traverse and map all streams and cutblock boundaries.
6. In environmentally sensitive selective harvesting areas, mark with orange paint all trees to be felled. Use "X" to denote "do not fall in this direction," and "O" to denote "O.K. to fall in this direction." Trees that require on-site supervision during falling and yarding should be circled with orange paint and painted with the words **SUPERVISOR**. In other selective areas, the trees to be felled should be marked with the letter "S" in orange paint.

Falling Treatments

1. Clearcut
   - All trees *to be felled away from streams* must be marked with "red candy-striped and hi-viz pink" ribbon (or, if the stream is used as a boundary of the cutblock, then with "red candy-striped and orange-glow" ribbon).
   - All trees *to be felled away from streams where possible* must be marked with "blue candy-striped" ribbon (or, if a stream is used as a boundary of a cutblock, then with "blue candy-striped" ribbon along with "orange-glow" ribbon).
   - All non-merchantable trees (small conifers and alder) along streambanks are to be left standing where it is safe to leave them.
   - Any trees that cannot be felled away from streams are to be left standing. The exception is snags, which, if they pose a danger, must be felled regardless of streams.

2. Selective

   - All trees to be felled must be marked with orange paint. An "X" denotes "do not fall in this direction." An "O" denotes "O.K. to fall in this direction." A line of orange paint circling a tree means "do not fall without a supervisor or agency personnel present."
   - If you are in doubt about whether a tree can be felled in its marked direction, leave the tree standing or discuss the options with a supervisor.
   - Fallers must plan ahead to minimize damage to residual trees. Sidewinders should be felled unless they will enter a stream.
   - Saw fueling should be done away from streams.
   - Bucking should be planned in such a way that sawdust entering streams is minimized.
   - If you are in doubt, do not proceed: ***call your supervisor***.
   - Snags may be felled where safety dictates, regardless of streams.
   - If material enters a stream inadvertently, notify your supervisor.

Yarding Treatments

1. Locate all service landings in areas where fuel spills will not enter streams.
2. In selective areas, if turn size exceeds capacity, ride turn to the ground and then release. Do not "pickle turn" unless safety is in question.
3. Minimize damage to standing trees as much as possible.
4. Do not land logs over culverts or streams.
5. Mark tops and limbs to be removed from floodplain areas with "lime-glow" ribbon.